Cosmic firework from colliding neutron stars, observed in gravitational and electromagnetic waves during August 2017.
Launch of Vigyan Pratibha Project at HBCSE, Mumbai by Dr. Sekhar Basu (Secretary, DAE) on 31 July 2017

Vigyan Pratibha Students Workshop

Vigyan Pratibha Teachers Workshop

Vigyan Pratibha Outdoor Activities with Students

The cover graphic has been created by Christopher Evans and Karan Jani at the Center for Relativistic Astrophysics, Georgia Institute of Technology, and is reproduced with their kind permission.
<table>
<thead>
<tr>
<th>Contents</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Council of Management</td>
<td>1</td>
</tr>
<tr>
<td>Honorary Fellows</td>
<td>2</td>
</tr>
<tr>
<td>Preface</td>
<td>3</td>
</tr>
<tr>
<td>Awards and Distinctions</td>
<td>5</td>
</tr>
<tr>
<td>Faculty</td>
<td>8</td>
</tr>
<tr>
<td>Academic Council</td>
<td>13</td>
</tr>
<tr>
<td>Administration and Services</td>
<td>14</td>
</tr>
<tr>
<td><strong>School of Mathematics</strong></td>
<td></td>
</tr>
<tr>
<td>Centre for Applicable Mathematics, Bengaluru</td>
<td>21</td>
</tr>
<tr>
<td><strong>School of Natural Sciences</strong></td>
<td></td>
</tr>
<tr>
<td>Department of Astronomy and Astrophysics</td>
<td>25</td>
</tr>
<tr>
<td>Department of Biological Sciences</td>
<td>43</td>
</tr>
<tr>
<td>Department of Chemical Sciences</td>
<td>55</td>
</tr>
<tr>
<td>Department of Condensed Matter Physics and Materials Science</td>
<td>73</td>
</tr>
<tr>
<td>Department of High Energy Physics</td>
<td>89</td>
</tr>
<tr>
<td>Department of Nuclear and Atomic Physics</td>
<td>97</td>
</tr>
<tr>
<td>Department of Theoretical Physics</td>
<td>117</td>
</tr>
<tr>
<td>Research Facilities</td>
<td>135</td>
</tr>
<tr>
<td><strong>TIFR Centres</strong></td>
<td></td>
</tr>
<tr>
<td>International Centre for Theoretical Sciences, Bengaluru</td>
<td>151</td>
</tr>
<tr>
<td>National Centre for Radio Astrophysics, Pune</td>
<td>173</td>
</tr>
<tr>
<td>National Centre for Biological Sciences, Bengaluru</td>
<td>199</td>
</tr>
<tr>
<td>TIFR Centre for Interdisciplinary Sciences, Hyderabad</td>
<td>223</td>
</tr>
<tr>
<td>Homi Bhabha Centre for Science Education, Mumbai</td>
<td>245</td>
</tr>
<tr>
<td><strong>School of Technology and Computer Science</strong></td>
<td></td>
</tr>
<tr>
<td>General Facilities and Services</td>
<td>273</td>
</tr>
<tr>
<td><strong>Publications, Lectures, Training, etc.</strong></td>
<td></td>
</tr>
<tr>
<td>Publications</td>
<td>293</td>
</tr>
<tr>
<td>Lectures Given Elsewhere</td>
<td>333</td>
</tr>
<tr>
<td>Lectures, Seminars and Colloquia at TIFR</td>
<td>343</td>
</tr>
<tr>
<td>Training</td>
<td>367</td>
</tr>
<tr>
<td>Science Popularisation and Public Outreach</td>
<td>377</td>
</tr>
<tr>
<td>Obituaries</td>
<td>384</td>
</tr>
</tbody>
</table>
Council of Management

Mr. Ratan N. Tata (Chairman)
Chairman, Sir Dorabji Tata Trust

Mr. R. K. Krishna Kumar (till November 9, 2017)
Trustee, Sir Dorabji Tata Trust

Mr. R. Venkataramanan (since November 10, 2017)
Managing Trustee, Sir Dorabji Tata Trust

Dr. Sekhar Basu (till January 14, 2018)
Chairman, Atomic Energy Commission & Secretary to the Govt. of India
Department of Atomic Energy

Mr. Ranajit Kumar (since January 15, 2018)
Head, Nuclear Control and Planning Wing
Department of Atomic Energy

Ms. Vandita Sharma (till May 14, 2017)
Member (Finance), Atomic Energy Commission

Mr. R. Sridharan (from May 15, 2017 to November 21, 2017)
Member (Finance), Atomic Energy Commission

Ms. Sanjeevanee Kutty (since November 22, 2017)
Member (Finance), Secy. Dept. of Ex-servicemen welfare, Ministry of Defence

Prof. C. N. R. Rao
Hon. President, Jawaharlal Nehru Centre for Advanced Scientific Research

Dr. Shekhar Mande
Director, National Centre for Cell Science, Nominee of the Govt. of Maharashtra

Dr. Kasturirangan
Trustee, Raman Research Institute Trust

Prof. Sandip P. Trivedi
Director, Tata Institute of Fundamental Research
Honorary Fellows

Present
Prof. Sir Michael Atiyah
Prof. P.R. Deligne
Prof. Richard Ernst
Prof. Murray Gell-Mann
Prof. David Gross
Prof. Anthony Hewish
Prof. Leon M. Lederman
Prof. G.A. Margulis
Prof. Andre Martin
Prof. S. Miyake
Prof. D. Mumford
Prof. M.S. Narasimhan
Prof. T.V. Ramakrishnan
Prof. C.N.R. Rao
Prof. B.V. Sreekantan
Prof. James Dewey Watson
Prof. Sir Arnold Wolfendale
Prof. Samuel C. Ting
Prof. C.S. Seshadri
Prof. S.R.S. Varadhan
Mr. Ratan N. Tata
Prof. Govind Swarup
Prof. M.S. Raghunathan
Prof. Ramanath Cowsik

Past
Prof. H. Alfven
Prof. P.M.S. Blackett
Prof. Felix Bloch
Prof. Niels Bohr
Prof. Armand Borel
Prof. S.N. Bose
Prof. Harish Chandra
Prof. S. Chandrasekhar
Sir John Cockcroft
Prof. Francis Harry Compton Crick
Prof. R.H. Dalitz
Prof. P.A.M. Dirac
Prof. S. Dhawan
Prof. P.L. Kapitza
Prof. Jacques L. Lions
Dr. John Mathai
Shri Jawaharlal Nehru
Prof. Bernard Peters
Prof. Lord Porter
Prof. C.F. Powell
Prof. C.V. Raman
Dr. R. Ramanna
Prof. G.N. Ramachandran
Prof. B.B. Rossi
Prof. A. Salam
Prof. L. Schwartz
Prof. C.L. Siegel
Shri J.R.D. Tata
Prof. Andre Weil
Prof. A. Selberg
Prof. H.N. Sethna
Prof. V.L. Ginzburg
Prof. D. Lal
Prof. Obaid Siddiqi
Prof. M.G.K. Menon
Prof. K. Chandrasekharan
Prof. E.C.G. Sudarshan
It has been a good year for TIFR with respect to accomplishments in many different scientific domains. The first joint detection of gravitational waves and electromagnetic radiation from a binary neutron star merger (GW170817) provided unprecedented insights into many aspects of physics, astrophysics and cosmology. Researchers from the Department of Astronomy and Astrophysics were part of an effort that performed a generic-IPN test to probe the effects of dipole radiation in the data analysis of binary black hole events like GW170608, and GW170814 and the BNS event GW170817.

In Biological Sciences, using the murine malarial model, the long-term effect of a single episode of infection was studied. Separate research using rodents examined the epigenetic, molecular, cellular and cytoarchitectural basis of mood-related behavior generated in response to early adversity and pharmacological drugs used for the anxiety and depression therapy. Studies using zebrafish embryos suggested that application of controlled heat-shock at a certain stage of development could alter the ploidy without stalling the development.

In Chemical Sciences, a real-time Raman visualization of structural events on a donor-pi-acceptor backbone of a conjugated polymer subsequent to photoexcitation was recorded for the first time. Studies were performed on the synthesis of high surface area carbon nanospheres with wrinkled cages and their application in CO2 capture is being investigated. Techniques were devised to quantify messenger molecules in brain tissue without using any artificial labels.

In High Energy Physics, data for the CMS experiment at CERN, the Belle experiment, the GRAPES-III experiment and the HAGAR observatory are being analysed. GRAPES-III is undergoing hardware upgrade. The HAGAR group is developing a G-APD based camera for the future. Members are working as part of the LIGO Scientific Collaboration. With the data collected by this collaboration, several gravitational wave events were observed, notably the merger of two neutron stars along with the electromagnetic signals and an independent measurement of the Hubble constant became possible.

In Nuclear and Atomic Physics, experiments tracked a bunch of electrons traveling faster than light through a piece of glass to find out how long they actually live. In a significant breakthrough, scientists devised a high power radiation source in the terahertz (THz) region of the electromagnetic spectrum by irradiating common laboratory liquids like methanol, acetone, dichlorehane, carbon disulphide and water with moderate energy femtosecond laser pulses, ionizing the liquid and forming long plasma channels called filaments. In another crucial study, a team of scientists from TIFR and Institute of Plasma Research, Gandhinagar recreated magnetic turbulence on a table top in the laboratory.

In Condensed Matter Physics and Materials Science, the functioning of a fully programmable 3-qubit quantum processor using superconducting circuits was successfully demonstrated in the area of quantum computation. In Nanomaterials Physics, it was shown that metallic Selenium, due to its unique, chiral crystal structure, is able to rotate Terhertz radiation and this is ascribed to a novel, phonon-mediated mechanism. In the area of magnetism and superconductivity, extremely large positive magnetoresistance (MR) was observed in a high quality single crystal of MoSi2.

In Theoretical Physics, the first estimation of the hot circumgalactic medium from a cosmological sample of galaxies observed in both SZ and X-Ray was made, and shown to solve the galactic missing baryon problem. In Condensed Matter and Statistical Physics, a graduate level textbook on the theory of electrons in normal metals, *Landau Fermi Liquids and Beyond*, was completed. Under High Energy Physics, the ability of the proposed iron calorimeter (ICAL) detector at the India-based Neutrino Observatory (INO) to determine hadron shower direction was determined through simulations.

At the Homi Bhabha Centre for Science Education, the National Olympiad programmes in Astronomy, Biology, Chemistry, Junior Science, Mathematics and Physics continued to flourish. Overall, in all subjects, out of 30 participants from India, 10 gold, 12 silver, 4 bronze medals, and 4 honourable mentions were won at the international Olympiads in the year 2017. An interactive web-portal has been developed for the Vigyan Pratibha project—a new science talent nurture programme for students of Class 8–10 in Kendriya Vidyalayas (KVs), Navodaya Vidyalayas (JNVs), and Atomic Energy Central Schools (AECSs).

At the National Centre for Radio Astrophysics, Pune Phase-2 of the GMRT High Resolution Southern Sky (GHRSS) survey with the upgraded GMRT has begun and led to the discovery of two pulsars in the pilot phase. Using the Giant Metrewave Radio Telescope and the Karl G. Jansky Very Large Array, a radio relic that traces peripheral shock in a low-mass galaxy cluster PLCK G200.9-28.2 has been
discovered. This cluster is the lowest mass cluster known to have radio detected shock at its periphery.

At the National Centre for Biological Sciences, Bangalore, a study from the Biochemistry, Biophysics and Bioinformatics group provided insight into the mutations that occur in the prolonged stationary phase of *Escherichia coli*. The first National Cryo EM Facility in the country was established at NCBS. The facility is equipped with a 300 kV Transmission Electron Microscope (TEM) that can do both high-resolution structure determination of macromolecules in solution as well as in situ in cells by tomography.

At the International Centre for Theoretical Sciences, Bangalore, contribution was made to the tests of general relativity using the joint gravitational and gamma-ray observations of the binary neutron star merger GW170817/GRB170817A. In a study related to Fluid Dynamics and Turbulence, the Markov Random Field approach to describing the monsoon yielded first successful results.

At the TIFR Centre for Interdisciplinary Sciences, Hyderabad, in Biological Sciences, a novel role of a gene named *DYRK-A1* was identified in the regulation of gene expression. In a study related to Material Sciences, development of large area atomic layers and integration of them to electronic circuitries such as field effect transistors, photodetectors, and magneto-/magneto-dielectric devices were achieved. In Biological Chemistry and Molecular Biophysics group, research is underway to understand the molecular mechanisms of protein aggregation, which are involved in the pathology of Alzheimer’s disease and Type-2 diabetes.

In the School of Technology and Computer Science, research work was pursued in the areas of computer science as well as systems science. Under Complexity theory, a new simulation theorem that lifts parity decision tree complexity to asymmetric communication complexity was proved. In Quantum Computation, an efficient quantum algorithm was developed to estimate average gate fidelity using far lesser randomness than the previous state of the art.

At the School of Mathematics, a study found a new connection between stable random fields and Patterson-Sullivan measures. Many important contributions were made in the analysis of partial differential equations, scientific computation, control theory, inverse problems, stochastic analysis and in applications of mathematics at TIFR Centre for Applicable Mathematics, Bengaluru. The work on forced Sine-Gordon equation found application in the study of ferroelectric liquid crystals.

TIFR also ran a wide variety of Outreach and Science Popularisation programmes very successfully, bringing the
Awards and Distinctions

NATIONAL

Kanekar, Nissim (NCRA, Pune) - Shanti Swarup Bhatnagar Award 2017 (awarded by the Council of Scientific and Industrial Research, Govt. of India)

Bhalla, Upinder Singh (NCBS, Bengaluru) - Infosys Prize 2017 in Life Sciences (awarded by the Infosys Science Foundation)

Krishnan, Yamuna (NCBS*, Bengaluru) - Infosys Prize 2017 in Physical Sciences (awarded by the Infosys Science Foundation)

*recently moved to the University of Chicago

Munshi, Ritabrata (School of Mathematics) - Infosys Prize 2017 in Mathematical Sciences (awarded by the Infosys Science Foundation)

Dasgupta, Chandan (ICTS, Bengaluru) - S. N. Bose Medal (awarded by the Indian National Science Academy, New Delhi)

Chary, K.V.R. (DCS) - G.N. Ramchandran Gold Medal for Excellence in Biological Sciences and Technology 2017 (awarded by the Council of Scientific & Industrial Research, Govt. of India)

Raju, Suvrat (ICTS, Bengaluru) - Swarnajayanti Fellowship (awarded by the Department of Science and Technology, Govt. Of India)

Basu, Riddhipratim (ICTS, Bengaluru) - Ramanujan Fellowship (awarded by the Department of Science and Technology, Govt. of India)

Dasgupta, Basudeb (DTP) - Ramanujan Fellowship 2015–2020 (awarded by the Department of Science and Technology, Govt. of India)

Ghosh, Hiyaa (NCBS, Bengaluru) - Ramanujan Fellowship (awarded by the Department of Science and Technology, Govt. of India)

Raghunath, Vinodkumar Kutti (NCBS, Bengaluru) - Ramanujan Fellowship 2017–2022 (awarded by the Department of Science and Technology, Govt. of India)

Shivaprasad, P. V. (NCBS, Bengaluru) - Ramanujan Fellowship 2013–2018 (awarded by the Department of Science and Technology, Govt. of India)

Jaiswal, Manish (TCIS, Hyderabad) - Ramalingaswami Re-entry Fellowship for the year 2016-17 (awarded by the Department of Biotechnology, Govt. of India, Fellowship duration - 5 years)

Notani, Dimple (NCBS, Bengaluru) - DBT-Ramalingaswami Fellowship (awarded by the Department of Biotechnology, Govt. of India)

Basu, Riddhipratim (ICTS, Bengaluru) – ICTS-Simons Junior Faculty Fellowship

Khushalani, Deepa (DCS) - CRSI Bronze Medal (awarded by the Chemical Research Society of India)

Ninan, Joe Philip (DAA former student) - INSA Medal for Young Scientist 2017 (awarded by the Indian National Science Academy, New Delhi)

Yadav, Nisha (DAA) - INSA Young Historian of Science Award 2017 (awarded by the Indian National Science Academy, New Delhi)

Koley, Ujjwal (CAM, Bengaluru) - INSA Young Scientist Medal 2018 (awarded by the Indian National Science Academy, New Delhi)

Ghosh, Anish (School of Mathematics) - NASI SCOPUS Young Scientist Award 2017

Bhattacharjee, Subhro (ICTS, Bengaluru) - SERB Early Career Research Award (awarded by the Department of Science and Technology, Govt. of India)

Khatri, Rishi (DTP) - SERB Early Career Research Award 2016–2019 (awarded by the Department of Science and Technology, Govt. of India)

Kundu, Anupam (ICTS, Bengaluru) - SERB Early Career Research Award
The molecular origin of toxicity of the Amyloid Beta peptide

It is a mystery why the amyloid beta peptide, benign in its monomeric state, attacks membranes and becomes toxic when it forms oligomers. Oligomers are unstable, and this has prevented a structural understanding of this important question. Some models hypothesize that Abeta works like anti-microbial peptide, forming a ion-permeable channel on the membrane. However, this would typically imply an anti-parallel beta sheet character, while the abeta aggregates (mature ones that could be structurally characterized) appeared to be parallel. Using a combination of optical and solid state NMR spectroscopies, we showed that the early toxic oligomers are indeed anti-parallel in nature. [In collaboration with PK Madhu and Ravindra Venkatramani]

Fluctuations as a guide to abeta ligands

It is a challenge to design a candidate drug molecule for an intrinsically disordered protein (IDP), as rational drug design starts from the structure of the target protein. Yet, IDPs are at the heart of many incurable human diseases. We have demonstrated a new approach for drug design that is suitable for IDPs. We show that the dynamics of spontaneous fluctuations of an IDP is sensitive to a ligand, even if it does not have a stable interaction with the IDP. We have devised a cross-correlation fluorescence microscopy set up, which can measure the spontaneous equilibrium fluctuations at a ns time scale. We show that it is possible to quantitatively order the effects of an assortment of candidate drug molecules on the basis of their influence on the fluctuations.

New approaches for imaging monoamine neurotransmitters

There have been two major developments in our efforts to image monoamines in living cells. Monoamine neurotransmitters (such as serotonin) are a major class of messenger molecules used by neurons. We have previously developed techniques to image them in a label-free manner in living cells using multiphoton microscopy. However, quantification on the basis of the intensity of the images is prone to errors. We have now shown that concentration induced shift in the emission spectra can be used to internally calibrate the concentration of serotonin in living cells. In addition, we have simplified the technique for imaging monoamines, using a fluorogenic compound called ortho-Pthalaldehyde. This reacts with serotonin in the cell and forms a visibly fluorescent compound. This allows the visualization of monoamines without the use of the costly and complicated multiphoton microscope.

Single-Molecule Biophysics

Moving beyond the mechanical clamp: An exploration into differential mechanical stability of ubiquitin family proteins

Mechanical properties of proteins with a β-grasp/β-sandwich fold topology have been studied extensively by both single-molecule force spectroscopy experiments and steered molecular dynamics simulations (SMD), owing to their endurance towards high rupture forces. Previous studies have shown that the backbone hydrogen bonding network holding the terminal β-strands (β-clamp) in these proteins contributes prominently to their mechanical stability. However, the role of interactions beyond the β-clamp in providing mechanical resistance is not well understood. Ubiquitin family proteins, which share a common β-grasp fold including a β-clamp, exhibit distinct mechanical stability. The low sequence homology shared by these proteins implies a differential interaction network constituting the protein fold and this could serve as a paradigm to explore the role of collective structural contributions towards mechanical stability of a protein. Here, we explore the structural origin behind differences in the mechanical properties of three members of the ubiquitin family (ubiquitin, SUMO1 and SUMO2). SMD simulations have been employed to reveal a high resolution atomistic view of protein structural changes as they unravel under the influence of a mechanical force applied along their termini. The simulations corroborate experimentally observed differences in mechanical stability of these three proteins. We monitor collective structural changes to reveal the major secondary structural elements that contribute to their mechanical stability. Differential coupling between various β-strands and the α-helix results in differences in the mechanical stability.
(awarded by the Department of Science and Technology, Govt. of India)

Ramesh, Arati (NCBS, Bengaluru) - SERB Early Career Award
(awarded by the Department of Science and Technology, Govt. of India)

Gupta, Sourendu (DTP) - Dr. A.P.J. Abdul Kalam High Performance Computing Award 2017

Rama Govindarajan (ICTS, Bengaluru) - Platinum Jubilee Award of the Aerospace department of IISc

Mishra, Krishna Kumar (HBCSE – TIFR) - Homi Jehangir Bhabha Gold Prize" of the “Maharashtra Rajya Hindi Sahitya Academy” for the year 2016-17 under the category "Scientific-Technical"
(awarded by the Govt. of Maharashtra)

Mahan, Mj (School of Mathematics) - D.Sc (Honoris Causa)
(awarded by Gaud Banga University, 2017)

Sule, A. (HBCSE) - Youth Icon of the year 2018 Award
(awarded by Maharashtra Times, March 2018)

Krishna, Sudhir (NCBS, Bengaluru) - Old Cottonian of Eminence Award
(awarded by Old Cottonians' Association, Bengaluru)

Datta, Ankona (DCS) - Eminent and Empowered Women Award for a Scientist

INTERNATIONAL

Chary, K.V.R. (NMR) - Elected Fellow of The World Academy of Sciences (FTWAS) 2014

Venkatramani, Ravindra (DCS) - Fellow of the Royal Society of Chemistry, UK

Srinivas, V. (School of Mathematics) - Einstein Visiting Fellow for period 2016-19, Freie Universität, Berlin

Majumdar, Subhabrata (DTP) - Simon Fellow, ICTP, Trieste

Rakshit, Ananya (DCS) - Carl Storm International Diversity Fellowship for presenting her work at Gordon Research Conference on Metal in Biology held in January 2018 in California, USA.

Thirumalai, Vatsala (NCBS, Bengaluru) - Wellcome Trust-DBT India Alliance Senior Fellowship (2018–2023)

(awarded by Women Graduates Union, March 2018)

Ramakrishnan, Uma (NCBS, Bengaluru) - Featured in Indian women in Science calendar 2018

Fellows of the Indian National Science Academy (INSA), effective from January 1, 2018:
- Damle, Kedar S. (DTP)
- Mahan, Mj (School of Mathematics)
- Mandal, Gautam (DTP)
- Parameswaran, A.J. (School of Mathematics)
- Singh, K.P. (DAA, Retired)
- Tole, Shubha (DBS)

Fellows of the Indian Academy of Sciences, effective from January 1, 2018:
- Ghosh, Anish (School of Mathematics)
- Maiti, Sudipta (DCS)
- Sane, Sanjay P. (NCBS, Bengaluru)

Hosur, R.V. (NMR) - Director, UM-DAE Centre for Excellence in Basic Sciences, University of Mumbai, Kalina

Wadia, Spenta (ICTS, Bengaluru) - ICTS Homi Bhabha Chair Professor of the Infosys Foundation

Scientific Information Resource Centre (SIRC), TIFR - Wiley Library Award 2017 under the category ‘Digitally Transformed Research Library’
(awarded by Wiley India)

Notani, Dimple (NCBS, Bengaluru) - Wellcome-DBT IA intermediate Fellowship

Ghosh, Hiyaa (NCBS, Bengaluru) - Early Career Investigator Award

Mondal, Samsuzzoha (DCS) Biophysical Society 61st Annual Meeting Travel Award, New Orleans, USA, February, 2017

Badrinarayan, Anjana (NCBS, Bengaluru) - HFSP Career Development Award, March 2018

Ramakrishnan, Uma (NCBS, Bengaluru) - Welcome Trust DBT India Alliance Senior Investigator Award

Kale, Ruta (NCRA, Pune) - Young Scientist Award 2017
(awarded by the International Union of Radio Sciences)

Dasgupta, Jyotishman (DCS) - 2017 Young Scientist Award by Asian Photochemistry Association (APA)
Parameswaran, Ajith (ICTS, Bengaluru) - Azrieli Global Scholar
(awarded by the Canadian Institute for Advanced Research)

Parameswaran Ajith (ICTS, Bengaluru) - PI of the ‘Indo–U.S. Center for the Exploration of Extreme Gravity’ (Fundied by the Indo-US Science and Technology Forum; US PI: B.S. Sathyaprakash, Penn State)

Das, Sayani (DCS) - Nature Travel Grants Award to present her work at the Gordon Research Conference on Cell Biology of Metals, July 2017, Vermont, USA

Thutupalli, Shashi (NCBS and ICTS, Bengaluru) - Young Investigator Grant from the Human Frontier Science Program (HFSP)

Madhu, P. K. (TCIS, Hyderabad) - Elected as ISMAR (International Society for Magnetic Resonance) Council Member

Narayanan, T. N. (TCIS, Hyderabad) - Materials Research Society Membership Award (with MRS-2017 Travel Grant) - 2018 January–December

Iyer, Bala R. (ICTS, Bengaluru) - Chief Editor of the Journal Living Reviews in Relativity

Iyer, Bala R. (ICTS, Bengaluru) - Shared with the LIGO Scientific Collaboration:

- The UK Royal Astronomical Society 2017 Group Achievement Award in Astronomy, for the direct detection of gravitational waves by the LIGO detectors.
- 2017 Bruno Rossi Prize ‘for the first direct detections of gravitational waves, for the discovery of merging black hole binaries, and for beginning the new era of gravitational-wave astronomy.
- 2017 Einstein Medal from the Einstein Society in Bern, Switzerland
- 2017 Princess of Asturias Award for Technical and Scientific Research

Special Breakthrough Prize in Fundamental Physics was awarded to the international LIGO collaboration of which TIFR was a part. The participating individuals in the ICTS team were:
Ajith, P.
Ghosh, Abhirup
Ghosh, Archisman
Mukherjee, Arunava
Mishra, Chandrakant
Johnson-McDaniel, Nathan
Iyer, Bala.
This was awarded by the Fundamental Physics Prize Foundation.
Faculty

Trivedi, Sandip P. (Director)

School of Mathematics

Bhattacharya, Amitava
Bhattacharya, Siddhartha
Biswas, Indranil
Deshpande, Tanmay
Fakhruddin, N.
Ganapathy, Radhika
Ghate, Eknath P.
Ghosh, Anish
Holla, Yogish I.
Krishna, Amalendu
Mahan, Mj.
Munshi, Ritabrata
Nair, Arvind N.
Nitsure, Nitin

Parameswaran, A.J.
Prasad, Dipendra
Rao, C.S.
Rao, S. E. (till 31.08.2017)
Roushon, S.K.
Sankaranarayanan, A.
Sengupta, J.
Sridharan, Raja
Srinivas, V.
Subramaniam, S.
Trivedi, Vijayalakshmi G.
Varma, Sandeep V.
Venkataramana, T.N.

Adjunct Faculty

Fasel, Jean, Institut Fourier, France (till 31.03.2018)
Prasanna, Kartik, University of Michigan, USA (till 31.10.2019)
Velani, Sanju L., University of York, UK (till 31.03.2018)

TIFR Centre for Applicable Mathematics, Bengaluru

Aravinda, C.S.
Banerjee, Aagnid
Biswas, Imran H.
Ghoshal, Shyam Sundar
Gowda, G.D. Veerappa
Joseph, K.T. (till 31.03.2018)
Koley, Ujjwal
Krishnan, Venkateswaran P.

Praveen, C.
Ramaswamy, Mythily
Sandep, K.
Shrinivasan, P.K.
Sivaguru
Vadlamani, Sreekar
Vasudevamurthy, A.S.

School of Technology and Computer Sciences

Bhaskar, Umang
Chattopadhyay, Arkadev
Gupta, Ashutosh K.
Harsha, Prahlad
Juneja, Sandeep K.
Kavitha, T.
Narayanan, H.
Pandya, Paritosh K.

Prabhakaran, Vinod M.
Radhakrishnan, Jaikumar
Raja, N.
Saptharishi, Ramprasad
Sen, Pranab G.D.
Srivastava, Piyush
Vaze, Rahul

Adjunct Faculty

Basu, R., ICTS Bengaluru (from 01.09.2017)
Borkar, V.S., IIT, Bombay (till 31.03.2018)
Shah, Devavrat, M.I.T., Cambridge, USA (since 01.03.2018)
School of Natural Sciences

Department of Astronomy and Astrophysics

Bhattacharyya, Sudip Ojha, Devendra K.
Chatterjee, Sourav (since 19.02.2018) Puravankara, Manoj
Ghosh, Swarna K. Rao, A.R.
Gopakumar, A. Singh, K.P. (till 30.06.2017)
Hanasoge, Shrawan M. Singh, Tejinder P.
Joshi, Pankaj S. Vahia, Mayank N.
Mookerjea, Bhaswati Yadav, J.S. (till 31.01.2018)

Adjunct Faculty

Chakrabarty, Deepto, M.I.T., Cambridge, USA (till 31.03.2018)
Gizon, Laurent, MPI for Solar System Research, Germany (till 30.09.2017)
Henning, Thomas K., MPI for Astronomy, Germany (till 31.01.2019)

Department of Biological Sciences

Das Gupta, Shamik Nair, Sreelaja
Jarori, Gautam K. (till 30.06.2017) Rao, B.J.
Kolthur, Ullas, S. Ray, Krishanu
Koushika, Sandhya P. Sharma, Shobhona (till 28.02.2018)
Maithreyi, R. Narasimha Sonawane, Mahendra S.
Mallik, Roop Tole, Subha
Mishra, Mithilesh Vaidya, Vidita A.

Adjunct Faculty

Gaspar, Patricia, Institut du fer a Moulin Paris, France (till 31.10.2019)

Department of Chemical Sciences

Chary, K.V.R. Madhu, P.K.
Das, Ranjan Maiti, Sudipta
Dasgupta, Jyotishman Mazumdar, Shyamalava
Datta, Ankona Polshettiwar, Vivek
Hosur, R.V. Venkatramani, Ravindra
Khushalani, Deepa Wategaonkar, S.J.
Koti, A. Sri Rama

Adjunct Faculty

Horovitz, Amnon, Weizmann Institute, Israel (till 31.03.2018)
Huster, Daniel, University of Leipzig, Germany (till 31.05.2018)

Department of Condensed Matter Physics and Materials Science

Ayyub, Pushan Nigam, Arun K.
Bhattacharya, Arnab Paulose, P.L.
Deshmukh, Mandar M. Prabhu, Shriganesh S.
Dhar, S.K. Ramakrishnan, S.
Ghosh, Sandip Raychaudhuri, Pratap
Ghosh, Shankar
Gopal, Achanta V.
Maiti, Kalobaran

Sampathkumaran, E.V.
Thamizhavel, A.
Vijayaraghavan, R.

**Adjunct Faculty**

Gupta, S. Dutta, University of Hyderabad (till 31.08.2020)

**Department of High Energy Physics**

Acharya, B.S. (till 30.11.2017)
Aziz, Tariq
Banerjee, Sudeshna
Chimis, Varsha S.
Dugad, Shashi R.
Guchait, Monoranjan
Gupta, Sunil K.

Krishnan, N.
Majumder, Gobinda
Mazumdar, Kajari
Mohanty, Gagan B.
Mohanty, Pravata K.
Unnikrishnan, C.S.

**Adjunct Faculty**

Dasu, Sridhara Rao, University of Wisconsin, Madison, USA (till 31.10.2018)
Incandela, Joseph, University of California, USA (till 31.10.2018)

**Department of Nuclear and Atomic Physics**

Krishnakumar, E (till 30.11.2017)
Krishnamurthy, M.
Mathur, Deepak (till 30.04.2017)
Mazumdar, Indranil
Mishra, S.N.
Misra, Deepankar
Mujumder, Sushil A.

Nanal, Vandana S.
Pal, Subrata
Palit, Rudrajyoti
Pillay, R.G. (till 28.03.2018)
Prabhudesai, Vaibhav S.
Ravindra Kumar, G.
Tribedi, Lokesh C.

**Adjunct Faculty**

Garg, Umesh, University of Notre Dame, USA (till 28.02.2021)

**Department of Theoretical Physics**

Damle, Kedar S.
Dasgupta, Basudeb
Datta, Saumen
Dighe, Amol S.
Gadde, Abhijit (since 20.09.2017)
Gavai, Rajiv V.
Gupta, Sourendu
Khatri, Rishi
Majumdar, Subhabrata
Mandal, Gautam

Mathur, Nilmani
Minwalla, Shiraz
Raychaudhuri, Sreeerup
Roy, Tuhin S.
Sadhu, Tridib
Sensarma, Rajdeep
Sharma, Rishi
Sridhar, K.
Tripathi, Vikram
Trivedi, Sandip P.

**Adjunct Faculty**

Bali, Gunnar S., Universität Regensburg, Germany (till 31.10.2018)
Bhattacharyya, Gautam, SINP, Kolkata, India (till 31.12.2017)
Das, Sumit Ranjan, University of Kentucky, USA (till 28.02.2021)
Majumdar, Satya N., Université Paris-Sud, France (till 28.02.2021)
Ollitrault, Jean-Yves, Institut de Physique Théorique, France (till 30.04.2017)  

**Homi Bhabha Centre for Science Education**

Chandrasekharan, Sanjay  
Chunawala, Sugra I.  
De, Prithwijit  
Gupta, Ankush  
Joshi, Paresh K.  
Khaparde, Rajesh B.  
Ladage, Savita A.  
Mashood, K.K. (since 01.01.2018)

Mazumdar, Anwesh  
Mishra, K.K.  
Nag juruna, G.  
Subramaniam, K.  
Sule, Aniket P.  
Vartak, Rekha R.  
Vijapurkar, Jyotsna

**National Centre for Biological Sciences**

Badrinarayan, Anjana  
Bhalla, Upinder S.  
Chattarji, Sumantra  
Das, Ranabir  
Ghosh, Hiya S.  
Gosavi, Shachi S.  
Hasan, Gaiti  
Krishna, Sandeep  
Krishna, Sudhir  
Kunte, Krushnamegh  
Ladher, Raj K.  
Mathew, M.K.  
Mayor, Satyajit  
Notani, Dimple  
Olsson, Shannon B.  
Padinjar, Raghu  
Ramakrishnan, Uma  
Ramesh, Aarti  
Rao, Madan  
Sane, Sanjay P.  
Sankaran, Mahesh  
Sarin, Apurva  
Seshasayee, Aswin Sai Narain  
Shivaprasad, P.V.  
Sowdhamini, R.  
Sundaramurthy, Varadharajan  
Thattai, Mukund  
Thirumalai, Vatsala  
Thutupalli, Shashi  
Venkatesan, Radhika  
VijayRaghavan, K.  
Vinoth Kumar, K.R. (since 06.07.2017)

**Young Investigator Programme members:**  
Agashe, Deepa  
Brockmann, Axel

**Adjunct Faculty**

Jain, Sanjeev, NIMHANS, Bengaluru, India (till 31.08.2020)  
Karanth, Ullas, Centre for Wildlife Studies, Bengaluru, India (till 31.08.2020)  
Malhotra, Vivek, Centre for Genomic Regulation, Barcelona (till 31.08.2020)  
Ramaswami, Mani Trinity College, Dublin, Ireland (till 31.08.2020)  
Spudich, James A., Stanford University, USA. (till 31.08.2020)

**National Centre for Radio Astrophysics**

Bhattacharya, Bhaswati  
Chandra, Poonam  
Chengalur, Jayaram N.  
Ghosh, Swarna K.  
Gupta, Yashwant  
Ishwara Chandra, C.H.  
Joshi, Bhal Chandra  
Kale, Ruta (since 30.10.2017)  
Kanekar, Nissim  
Lal, Dharam Vir  
Manoharan, P.K. (till 28.02.2018)  
Mitra, Dipanjan  
Oberoi, Divya  
Roy Choudhury, Tirthankar  
Roy, Jayanta  
Roy, Subhasish  
Saikia, D.J. (till 31.01.2018)  
Sirothia, Sandeep K. (till 01.08.2017)
Adjunct Faculty

Verheijen, Marc A.W., Univ. of Groningen, The Netherlands (till 31.01.2019)

International Centre for Theoretical Sciences

Ajith, P.
Apte, Amit
Basu, Pallab
Basu, Riddhipratim (since 11.09.2017)
Bhattacharjee, Subhro
Dey, Rukmini
Dhar, Abhishek
Dhar, Avinash (till 31.08.2017)
Gopakumar, Rajesh
Govindarajan, Rama
Krishnamurthy, Vijay Kumar
Kulkarni, Manas
Kundu, Anupam
Loganayagam, R.
Raju, Suvrat
Ray, Samriddhi Sankar
Vasan, Vishal

TIFR Centre for Interdisciplinary Sciences

Agarwal, Vipin
Chandrasekhar, V. (since 19.06.2017)
Chary, K.V.R.
Dani, Adish (since 17.07.2017)
Das, Tamal
Garai, Kanchan
Jaiswal, Manish
Jana, Anukul
Karmakar, Smarajit
Krishnamurthy, M.
Madhu, P.K.
Mandal, Kalyaneswar
Mazumder, Aprotim
Mondal, Jagannath
Narayanan, T.N.
Perlekar, Prasad
Ramadas, Jayashree
Ramakrishnan, Raghunathan
Raman, Karthik V.
Sengupta, Surajit
Shirhatti, Pranav R. (since 17.07.2017)
Vallurupalli, Pramodh
Vig, Monika (since 10.07.2017)

INSPiRE Faculty: Ghosh, Pushpita
Mote, Kaustubh R.

Adjunct Faculty

Chattopadhyay, Amitabh, CC&MB, Hyderabad, India (till 31.05.2018)
Ramaswamy, Sriram, IISc, Bengaluru, India (till 31.01.2020)
Sastry, Srikanth, JNCASR, Bengaluru, India (till 30.09.2017)
Academic Council

Director & Chair, ACM - Prof. Sandip P. Trivedi

Dean, Graduate School & Convenor, ACM - Prof. Amol S. Dighe

Centre Director, HBCSE - Prof. K. Subramaniam

Centre Director, NCBS - Prof. S. Mayor

Centre Director, NCRA - Prof. S. K. Ghosh (till March 2018)
Prof. Yashwant Gupta (since March 2018)

Centre Director, TCIS - Prof. V. Chandrasekhar

Centre Director, ICTS - Prof. Rajesh Gopakumar

Dean, NSF - Prof. H.M. Antia

Dean, MF - Prof. C.S. Rajan

Dean, TCSF - Prof. Sandeep Juneja

Dean, HBCSE - Prof. Sugra Chunawala

Dean, NCRA - Prof. J. Chengalur

Dean, TCIS - Prof. Surajit Sengupta

Dean, ICTS - Prof. Rama Govindarajan

Dean, TIFR CAM - Prof. G.D. Veerappa Gowda

Dean, NCBS - Prof. Upinder Bhalla

Convenor, BSB - Prof. Shubha Tole

Convenor, CSB - Prof. Deepa Khushalani

Convenor, MSB - Prof. Nitin Nitsure (till October 2017)
Prof. Vijaylaxmi G. Trivedi (since October 2017)

Convenor, PSB - Prof. Sreerup Raychaudhuri

Convenor, TCSF - Prof. Vinod M. Prabhakaran

Chair, DAA - Prof. D. K. Ojha

Chair, DBS - Prof. Krishanu Ray

Chair, DCMPMS - Prof. Pushan Ayyub

Chair, DCS - Prof. S. Mazumdar

Chair, DHEP - Prof. Sudeshna Banerjee

Chair, DNAP - Prof. G. Ravindrakumar

Chair, DTP - Prof. Sourendu Gupta

Registrar - Wg Cdr George Antony (Retd.)

ISI, Delhi - Prof. Rajendra Bhatia

Director, LV Prasad Eye Inst. - Prof. D. Balasubramanian

IIT, Mumbai - Prof. Vikram M. Gadre
Administration and Services

ADMINISTRATION

Registrar & Secretary to the Council of Management:
Wg Cdr Antony, George (Retd.)

Deputy Registrar:
Abhyankar, A.M.
(officially, till 27.04.2017)
Gokhale, Sanjay B.
(since 28.04.2017)

Financial Advisor:
Rawat, Meenaxi
(on deputation, till 30.06.2017)

Secretary, Natural Science Faculty:
Punia, Punita

Officer-in-charge, School of Mathematics:
Vengurlekar, V.V.

Assistant Registrar (Academic):
Krishnamurthy, S.

Secretary, IWG:
Bapna, Divya

Head, Accounts:
Paithankar, Kishor S.

Head, Establishment:
Athanavale, Milind A.

Public Relations Officer:
Ambekar, Raju P.

Legal Officer:
Dixit, Sucheta

Purchase Officer:
Shekhar, G.K.
(till 02.10.2017)
Baghele, Deepak B.
(since 03.10.2017)

Stores In-charge:
Kanchan, Bipin G.
(till 30.06.2017)
Shekhar, G.K.
(01.07.2017 to 02.10.2017)
Baghele, Deepak B.
(since 3.10.2017)

Security & Fire Officer:
Joshi, Bharat B.

Administrative Officer (C), General Administration:
Felix, T.J.

Head, Administration, HBCSE:
Abhyankar, A.M.
(since 01.05.2017)

Head, Administration & Finance, NCBS, Bengaluru:
Pahwa, Pawan K.
(since 31.03.2017)

Head, Administration & Finance, NCRA, Pune:
Solanki, J.K.

Administrative Officer (D), CAM, Bengaluru:
Kannan, C.J.

Administrative Officer (C), ICTS, Bengaluru:
Doddain, Mukesh

Charge – Establishment, TCIS, Hyderabad:
Hari Prasad, D.

Administrative Officer (D), NBF, Hyderabad:
Manohar, D.

SERVICES

Chief Engineer, Tech. Services & Central Workshop:
Sinha, Sangam

Head, Medical Section:
Raghavan, Sandhya

Head, Information System Development Group:
Goel, Nihita

Head, Scientific Information Resource Centre:
Prabakaran, R.

Scientific Officer (F), Low Temperature Facility:
Srinivasan, K.V.
Algebra and Algebraic Geometry

The study of the completability of unimodular rows over rings was continued. A new proof of the existence of the Vaserstein group operation on unimodular rows of length three over rings of dimension 2 was given.

Let $A$ be an affine algebra over an algebraically closed field $k$ of characteristic $\neq 2$. Let $I$ be an ideal of $A$. Then the map from the relative orbit space (w.r.t. $I$) to the quotient group of the Symplectic group (of order 4) modulo its Elementary subgroup, is a symplectic Meninicke symbol relative to $I$.

Defined the Suslin–Vaserstein symbol $S_r$ from the orbit space of unimodular rows of length $(r+1)$ modulo the elementary subgroup to the Witt group of Suslin matrices w.r.t. $\text{EU}_m(R)$ and showed that this map is injective.

The maximum supporting point of the HK density function was studied and was proved that it is equal to F-threshold in two dimensional case. As a result a formula for F-threshold in term of the strong HN slopes of the associated bundle was obtained.

Working on parabolic bundles in positive characteristic. Had been working on the stratified bundles and shown in special cases that an isomorphism of etale fundamental group implies the isomorphism on stratified fundamental group. Had proved that certain mixed functions have Thom stratification.

Differential Geometry, Lie Groups and Related Areas, Topology

Worked on cubulating surface-by-free groups (joint with Jason Manning and Michah Sageev). These generalize the combination theorem of Wise to the case where edge groups are not quasiconvex.

We found a new connection between stable random fields (probability) and Patterson-Sullivan measures (hyperbolic geometry).

We have been working on developing a theory of character sheaves on general algebraic groups and studying their relationship with character theory of finite groups coming from algebraic groups. This builds on our previous work on character sheaves on solvable groups.

The isomorphism conjecture in A-theory was settled for a large class of Artin groups. As a consequence the pseudoisotopy case follows.

Number Theory and Automorphic Forms

For a connected quasi-split reductive algebraic group $G$ over a field $k$, which is either a finite field or a non-archimedean local field, $\theta$ an involutive automorphism of $G$ over $k$, let $K = G^\theta$. Let $K_1 = [K_0,K_0]$, the commutator subgroup of $K_0$, the connected component of identity of $K$. In this paper, we provide a simple condition on $(G,\theta)$ for there to be an irreducible admissible generic representation $\pi$ of $G$ with $\text{Hom}_{K_1}[^r\mathbb{C}] \neq 0$. The condition is most
transparent to state in terms of a real reductive group $G_0(R)$ associated to the pair $(G,\theta)$ being quasi-split.

We prove an asymptotic formula for the counting function of $y$-friable numbers in a certain range, using the saddle point method. Further, we also prove certain reasonable upper bounds for the counting function of $y$-friable numbers for various ranges of $y$ whose proofs are comparatively simpler than the earlier ones. Though these bounds need not be the best estimates, these are certainly useful in applications.

Assuming strong Riemann hypothesis and an upper bound on the Gonek–Hejhal sum, the upper bound for the Mertens sum is improved.

An earlier result of Kohnen on non-vanishing of $L$ functions of cusp forms inside the critical strip was generalised to derivatives of arbitrary order of the $L$ functions.

An upper bound for the first negative simultaneous Hecke eigenvalues was proved for a pair of Maass cusp forms for the full modular group. A tetrachotomy was proved for the reductions of Galois representations of slope $\frac{3}{2}$ and exceptional weights.

The first step in the construction of a $p$-adic Asai $L$-function for modular forms over imaginary quadratic fields was made.

**Interdisciplinary**

Worked on the structure of Unicyclic non-KE graphs. This implied few conjectures of Levit and gave a simpler proof of an earlier result.

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**Members**


**Adjunct Faculty**

Kartik Prasanna (University of Michigan, USA)

**Visiting Fellows**

Kalyan Banerjee, Ashwin Deopurkar, Aditya Karnataki (till 30.09.17), Tohru Kohrita, Mitra Koley, Hengfei Lu, Vivek Mukundan (till 31.08.17), Husney Parvez (till 31.10.17), Tali Pinsky (till 31.07.17), B. Ravinder (till 17.03.17), Gunja Sachdeva, Biswajyoti Saha, Ekata Saha, Vivek Sahu (till 31.07.17), Subham Sarkar, R. Sivaguru (till 31.07.17)

**Research Scholars**


**Scientific Staff**

V. Nandagopal, Vishal Sailor

**Administrative Staff**

National and International Involvement

E. Ghate
1. Member, SERB, Program Advisory Committee, Mathematical Sciences
2. Member, CSIR Project Committee for Mathematical Sciences

Mahan Mj
1. Associate Editor, Infosys Science Foundation Series in Mathematical Sciences, Springer
2. Member, Editorial Board, Proceedings of Indian Academy of Sciences, Mathematical Sciences, 2015–2018
3. Member, Editorial Board, Ramanujan Math society lecture note series, 2015–18
5. Member, NBHM – 2015–2019
6. Member, INSA–ICSU – 2016–2019
7. Member, SERB-PAC – 2015–2018
8. Member, AFS syllabus committee, 2016
9. Member, Board of Studies, Presidency University, Kolkata, 2015–2019
10. Member, Governing Council of Indian Association for Cultivation of Sciences, Kolkata, 2016–2019
11. Member, Management Board of International Center for Theoretical Sciences, Bengaluru, 2017–2020

Arvind Nair
Member, Apex Committee, National Center for Mathematics

Nitin Nitsure
2. Member, Sectional Committee for Mathematics, Indian Acad. Sci.
3. Member, Governing Council, Chennai Mathematical Institute
4. Member, Governing Body, Bhaskaracharya Pratishthana
5. Academic Secretary and Member Apex Committee, National Center for Mathematics

Visits

Tanmay Deshpande
1. University of Sydney, Australia, 4–8 December 2017
2. Philipps Universität, Germany, 22–26 January 2018

E. Ghate
Université Paris 6, France, April 21 – June 23, 2017

Anish Ghosh
1. University of York
2. University of Houston
3. University of Strasbourg

Mahan Mj
1. Oberwolfach, Germany, October 2017
2. Institut Fourier Grenoble, France, October 2017
3. HSE, Laboratory of Algebraic Geometry, Moscow, June 2017

A. Sankaranarayanan
1. Life member, Hardy-Ramanujan Society, Bangalore
2. Life member, Ramanujan Mathematical Society, Chennai
3. Fellow, The National Academy of Sciences, Allahabad
4. Life member, Indian Mathematical Society, Delhi
5. Member, Editorial Board, Journal NASI Letters, Allahabad
6. Member, Editorial Board, International Journal of Mathematics and Scientific Computing (IJMSC, Vel Tech Dr. RR & Dr.SR Technical University, Chennai)
7. Member, Editorial Board, Journal of Applied Mathematics & Informatics (JAMI)

V. Srinivas
2. Office bearer, International Mathematical Union, Member at Large of Executive Committee
3. Chairman, National Board for Higher Mathematics
4. Ex-officio Member, INSA National Committee for Mathematics
5. Secretary and Convener, INSA Sectional Committee-I
6. Member, International Peer Review Panel, Peking University School of Mathematical Sciences and of Beijing International Centre for Mathematical Research, Beijing, China, 2–5 November 2017
**Invited Talks**

**Tanmoy Deshpande**
Centers of bimodule categories and induction-restriction functors. Workshop on Tensor Categories, Hopf Algebras and Quantum Groups at Philippus Universitität, Marburg, Germany, 22 January 2018

**Radhika Ganapathy**
On some Hecke algebra isomorphisms over close local fields. Mumbai-Pune Number theory seminar, February 2018

**E. Ghate**
4. Sums of Fractions and Finiteness of Monodromy. Shrikhande Conference, University of Mumbai, January 24, 2018

**Anish Ghosh**
1. Lecture series, University of Pune, January 2018

**Arrind N. Nair**
Research visit, University of Michigan, Ann Arbor, April 25, 2017 – May 22, 2017

**Nitin Nitsure**
1. Institut de Mathematiques de Jussieu, Universite Pierre et Marie Curie, Paris 6, France, 01 June 2017 – 30 June 2017 (for research)
2. Delivered invited lecture at the conference “Vector bundles on algebraic varieties”, Institute for Basic Science, POSTECH, Pohang, Korea 29 October – 04 November 2017

**Dipendra Prasad**
University of Maryland (4 months), August 25 to Dec 23, 2017

**C. S. Rajan**
IHEIS, France, June 15–July 15, 2017

**A. Sankaranarayanan**
1. Graduate School of Mathematics, Nagoya University, Japan, 19.08.2017 – 26.08.2017
2. Department of Mathematics and Computer Science, Adam Mickiewicz University, Poznań, Poland, 03.09.2017 – 09.09.2017
3. Department of Mathematics, Yonsei University, Seoul, Republic of Korea, 18.03.2018 – 26.03.2018
4. Department of Mathematics, University of Hyderabad, India, September 17–23, 2017
5. Department of Mathematics, IIT Ropar, Chandigarh, India, December 21–26, 2017
6. Department of Mathematics, PSG College of Technology, Coimbatore, January 03–07, 2018

**V. Srinivas**
2. Workshop on K-Theory, Hausdorff Inst., Univ. of Bonn, Germany; 25–30 June 2017
4. Workshop on Homological Conjectures, Math. Sciences Research Institute, Berkeley, CA, USA, 12–16 March, 2018
5. Purdue University, IN, USA, 17–27 March, 2018

**Vijaylaxmi Trivedi**
1. Freie Universität, Berlin, May 7–30, 2017
2. MSRI, Berkeley, California, March 12–16, 2018
3. Purdue University, West Lafayette, March 18–25, 2018
Nitin Nitsure
1. Quadric invariants and degeneration in lisse-etale topology. Institut de Mathematiques de Jussieu, 22 June 2017
2. Schematic Harder-Narasimhan stratification for families of principal bundles in higher dimensions. Conference talk in “Vector bundles on algebraic varieties”, Institute for Basic Science, POSTECH, 2 November 2017

Dipendra Prasad
1. Ext-analogue of branching laws for Classical groups. Weizmann Institute, June, 2017

C. S. Rajan

Ravi A. Rao

A. Sankaranarayanan
3. Riemann Hypothesis and its current status. Workshop on Algebraic Number Theory, University of Hyderabad, India, September 18, 2017
5. Riemann zeta-function and some conjectures. International Conference on Applied Mathematical Modelling (ICAMM 2018), PSG College of Technology, Coimbatore, January 4–6, 2018

J. Sengupta
Simultaneous non-vanishing of automorphic L functions. Automorphic forms workshop, Tufts University, Massachusetts, U.S.A., March 2018

V. Srinivas
A relative version of Gieseker’s problem on stratified vector bundles. Workshop on K-Theory and related fields, Hausdorff Centre, Bonn, Germany, 30 June 2017

Vijaylaxmi Trivedi
2. Towards Hilbert-Kunz density functions and multiplicities in Characteristic 0, CAAG-2017, IISER Pune, December 2017
3. Some applications of Hilbert-Kunz density functions to toric varieties. International Conference in Mathematics: celebrating centenary year of Professor S. S. Shrikhande, University of Mumbai, January 2017
4. Hilbert-Kunz density function and some applications. Commutative Algebra Seminar, Purdue University, 21 March 2017

Conference Organized by the School

Distinguished Lectures in Dynamics
TIFR, April 10 – 14, 2017 (Organising committee members: S. G. Dani and Anish Ghosh)

National Conference on Commutative Algebra and Algebraic Geometry
IISER Pune, December 5 – 8, 2017 (Organising committee members: Ravi A. Rao, Vivek Mohan Mallick, A.J. Parameswaran, Krishna Kaipa and Rabeya Basu)

Analytic Geometry
TIFR, March 26 – 30, 2018 (Organising committee members: Indranil Biswas and A.J. Parameswaran)

Non-DAE Research Projects

Indranil Biswas
J.C. Bose Fellowship

Anish Ghosh
1. SERB MATRICS Grant MTR/2017/000021, 2018–2021
2. DST Swarnajayanti award, 2017–2022
3. India-France CEFIPRA grant (co-PI Arnaldo Nogueira), 2017–2020
4. PI ISF-UGC grant (co-PI A. Nevo), 2014–2017
Mahan Mj
1. J. C. Bose Fellowship
2. Surface group representations and geometric group theory, MATRICS MTR/2017/000005 (2018–21) SERB/DST Project
3. Interactions between dynamical systems, geometry, and number theory, Indo–French CEFIPRA Project no. 5801 (2017–2020)

D. Prasad
J.C. Bose Fellowship, 2015–19

V. Srinivas
J. C. Bose Fellowship

T. N. Venkataramana
J.C. Bose Fellowship
Many important contributions were made in the analysis of partial differential equations, scientific computation, control theory, inverse problems, stochastic analysis and in applications of mathematics.

In an important work Serrin's symmetry result was established for the highly degenerate normalized p-laplacian for which strong comparison is not known. A weighted spectral gap classification and a version of the Agmon-Allegretto-Piepenbrink Principle characterising the subcritical/critical operators were proved for the Schrödinger operator \( \Delta + V \) where \( V \) is a locally integrable potentials called balanced potential. A strong unique continuation result was obtained for the nonlocal parabolic equation \( (\partial_t - \Delta) u = Vu; 0 < s < 1 \) with certain structural assumptions on the potential \( V \). A \( \Gamma \), \( \propto \) Schauder estimates near a \( C^{1,\propto} \) non-characteristic portion of the boundary for perturbations of horizontal Laplaceans in Carnot groups is obtained and the proof provides an alternate viewpoint on boundary regularity in Carnot groups. Uniform regularity estimates in the time direction and \( C^1 \) regularity of the free boundary at certain points were obtained for the obstacle problem for the fractional heat equation. A sharp version of the Sobolev inequality known as the Adams inequality was established on Hadamard manifolds with strictly negative curvature and Ricci curvature bounded from below. Rate of convergence for a monotone approximation for nonlocal Isaacs equations were obtained.

New exact solutions which are constants on hyperplanes with a fixed normal are constructed for the multidimensional zero-pressure gas dynamics system in 3-space dimensions. A necessary and sufficient condition for a solution of scalar conservation laws to admit a single shock in finite time is established.

A convergence result together with rate of convergence for the sequence of approximate solutions generated by the finite difference scheme for conservation laws driven by a homogeneous multiplicative Levy noise is established and the limits are identified as the unique entropy solution of the underlying problem. A notion of stochastic entropy solutions, a finite difference multilevel Monte Carlo algorithm and a multilevel Monte Carlo method based on a finite volume scheme were designed for a degenerate parabolic convection-diffusion equations where the convective and diffusive fluxes are allowed to be random. Various distributional aspects of certain geometric characteristics of random fields defined on continuous and discrete random fields were obtained.

A fully non-linear conjugate gradient scheme was proposed to study the non-linear inverse problem of reconstructing an electric conductivity distribution of a medium from certain interior power density functionals. The microlocal analysis of the ray transform of symmetric \( m \)-tensor fields restricted to all lines passing through a curve in \( \mathbb{R}^n \) satisfying certain geometric conditions was studied.

An analysis of stabilization of incompressible flow in a two dimensional polygonal domain was carried out. Several equivalent conditions for stabilizability using an unbounded control operator, are derived.

The work done on forced sine-Gordon equation attracted the attention of many and found application in the study of ferroelectric liquid crystals. In an ongoing project aimed at analysing the available monsoon related data, a model is proposed by blending classical non-parametric statistics with state of the art techniques pervading the machine learning community to model the rainfall patterns over the Indian landmass during monsoon season. In the process a novel technique of using Markov random fields to incorporate spatial and temporal coherence of rainfall patterns is proposed. Temporal evolution of the monsoon patterns, using the proposed method is studied, and the results appear very promising.
Members

Research Scholars

Scientific Staff
Shrikant Gaikwad, Veena K., T. Viswanathan,

Inspire Faculty
Divyang Bhimani

Administration
C. J. Kannan, G. Kannan, M. Pramila Kumari, S. K. Mahalakshmi, Fariya Suhael

Auxillary Staff
A. Abraham, S. Shanthi, A. Shivakumar, P. Desaiah, Joyce Devaraj, M. V. Venkatachalaiah

National and International Involvement

C. S. Aravinda
1. Member, Editorial Boards of
   (i) Hardy Ramanujan Journal,
   (ii) RMS Newsletter,
   (iii) Mathematics Student and
   (iv) Bhavana
2. Member, Executive Committee, Indian Mathematics Consortium (TIMC)
3. Member, SERB Expert Committee

G. D. Veerappa Gowda
Member, Editorial Board, Indian Journal of Pure and Applied Mathematics

K. T. Joseph
1. Member, INSA sectional committee 1 (Mathematical sciences), January 2015–December 2017
2. Associate Editor, Indian Journal of Pure and Applied Mathematics (January 2018)

Sandeep K.
1. Member, Editorial board, Indian Journal of pure and applied mathematics
2. Member, Editorial board, Journal of Ramanujan mathematical society
3. Member, Research Council, Kerala School of Mathematics, Kozhikode

Mythily Ramaswamy
1. Associate Editor, Boundary Value Problems, A Springer open journal
2. Member, Editorial Boards of
   (i) J1 Ramanujam Mathematical Society, India,
   (ii) Proceeding of Mathematical Sciences, Indian Academy of Sciences
3. Member, Board of Governors, IIT Gandhinagar (since March 2016) and NIT Calicut (since May 2016)
4. Member, Standing Committee, IISERs, March 2016
5. Member, Project Advisory Committee, SERB, Sep 2015

Visits

C. S. Aravinda
Department of Mathematics, University of Zurich, Zurich, Switzerland, 9–29 October, 2017

Imran H. Biswas
University of Pau, France, March – June 2018

Praveen Chandrashekar
1. PDES on the Sphere 2017, ENS, Paris, 3–7 April, 2017
2. TOY Workshop, NCAR, Boulder, 14–27 May, 2017
3. Visit to Prof. Dinshaw Balsara, University of Notre-Dame, 27 May – 7 June 2017
Invited Talks

C. S. Anuradha
2. Tiling patterns and nature (Talk in Kannada). Refresher course for teachers, Channabasaveshwara Institute of Technology, Gubbi, Karnataka, 19 January, 2018
3. Non-orientability, Klein bottle and dimension 3. Bharathiar University PG extension centre, Erode, Tamil Nadu, 23 February, 2018

Imran H. Biswas
1. On the rate of convergence for monotone numerical schemes for nonlocal Isaacs equations. NPDE2017
2. Recent developments in Nonlinear PDEs and Applications. TIFR-CAM, Bangalore, Nov 1–4, 2017

G. D. Veerappa Gowda
3. A finite volume method for a two phase multi-component polymer flooding. Inaugural meet of Indian chapter of Inter Pore, IIT Delhi, Dec. 14, 2017

Shyam Sundar Ghosal
2. Structure of the solutions for scalar conservations laws in one space dimension. Symposium Talk, ISIAM, Nehru Academic and Professional Excellence Award

Sreekar Vadlamani
On one year sabbatical leave from TIFR-CAM to visit the Department of Statistics at Lund University, Sweden, August 14, 2017 – August 13, 2018

Amritsar, Feb, 2018

K. T. Joseph
1. On the mordern theory linear hyperbolic systems, an overview starting with the work of Hadamard. SERBDST
2. National work shop on analytical and numerical solutions of PDES. Sponsored by NBHM-DAE, NIT Surkal, December 18–22, 2017

Sandeep K.
1. Inequalities and their invariance and symmetry properties. First BRICS mathematics conference, Beijing, China, August 21–25, 2017
2. Moser-Trudinger and Adams Inequalities. ISIAM Conference, Sharda University, New Delhi, Feb, 5, 2017
4. Extremals of inequalities and their uniqueness. Colloquium, ISI Bangalore, February 1, 2018

A. S. Vasudeva Murthy
1. On the wave equations of Kirchoo-Narasimha and Carrier. Recent advances in PDE, IIT Mumbai, June 10, 2017
2. On the radiative transfer equation. Discussion meeting on teaching of differential equations in India, Indian Academy of Sciences, Bangalore, Feb. 26, 2018

Mythily Ramaswamy
1. Ingham inequality. Plenary talk in the International Conference on Mathematical Analysis and Applications in Mathematical Modelling, Jadavpur University, January 9, 2018
2. Ingham inequalities and applications. International Conference on Mathematics, Department of Mathematics, University of Bombay, January 25, 2018

Conferences Organized by the Centre

Recent developments in Partial Differential Equations
TIFR-CAM, Bengaluru, August 17 – 18, 2017 (Organisers: G. D. Veerappa Gowda and Shyam Sundar Ghosal)

Recent developments in Nonlinear Partial Differential Equations and Applications
TIFR-CAM, Bengaluru, November 1 – 4, 2017 (Organisers: Agnid Banerjee and K. Sandeep)
Non-DAE Research Projects

Imran H. Biswas
Evolutionary Partial Differential Equations with Lévy noise (Funded by INSA)

Shyam Sundar Ghoshal
The Inspire Faculty Award (research grant) (Funded by DST), November 2016–November 2021

Venkateswaran P. Krishnan
Conical Radon transforms and their applications in tomography, August 2016–July 2019 ([Funded by US National Science Foundation Research grant])
PI: Gaik Ambartsoumian, Co-PI: Venkateswaran P. Krishnan

Mythily Ramaswamy (with Spenta Wadia)
Managing AIRBUS Corporate Foundation Chair Funds together, ICTS-TIFR, for 4 years from 2013
School of Natural Sciences
Theoretical Astrophysics

Solar Physics

Renormalization group theory outperforms other approaches in statistical comparison between upscaling techniques for porous media

Determining the pressure differential required to achieve a desired flow rate in a porous medium requires solving Darcy's law, a Laplace-like equation, with a spatially varying tensor permeability. In various scenarios, the permeability coefficient is sampled at high spatial resolution, which makes solving Darcy's equation numerically prohibitively expensive. As a consequence, much effort has gone into creating upscaled or low-resolution effective models of the coefficient while ensuring that the estimated flow rate is well reproduced, bringing to the fore the classic tradeoff between computational cost and numerical accuracy. Here we perform a statistical study to characterize the relative success of upscaling methods on a large sample of permeability coefficients that are above the percolation threshold. We introduce a technique based on mode-elimination renormalization group theory (MG) to build coarse-scale permeability coefficients. Comparing the results with coefficients upscaled using other methods, we find that MG is consistently more accurate, particularly due to its ability to address the tensorial nature of the coefficients. MG places a low computational demand, in the manner in which we have implemented it, and accurate flow-rate estimates are obtained when using MG-upscaled permeabilities that approach or are beyond the percolation threshold. [S. M. Hanasoge, U. Agarwal, K. Tandon and V. Koelman]

Measurement process and inversions using helioseismic normal-mode coupling

Normal modes are coupled by the presence of perturbations in the Sun, providing a unique and little-explored helioseismic technique with which to image the solar interior. The process of measuring coupling between normal modes is straightforward, much more so when compared with other prevalent helioseismic techniques. The theoretical framework to interpret these measurements is well developed with the caveat that it applies only in the case where the entire surface of the Sun is observed. In practice however, the limited visibility of the Sun and line-of-sight related effects diminish the resolution of the technique. Here, we compute realistic sensitivities of normal-mode coupling measurements to flows in the solar interior and describe how to mitigate the sometimes overwhelming effect of leakage. The importance of being able to isolate individual spherical harmonics and observe the full Sun, to which future solar observatories may aspire, is thus highlighted in our results. In the latter part of the article, we describe the noise model for the variance of coupling coefficients, a critical component to the process of inference. [S. M. Hanasoge]

Asymmetry of Line Profiles of Stellar Oscillations Measured by Kepler for Ensembles of Solar-like Oscillators: Impact on Mode Frequencies and Dependence on Effective Temperature

Oscillation properties are usually measured by fitting symmetric Lorentzian profiles to the power spectra of Sun-like stars. However, the line profiles of solar oscillations have been observed to be asymmetrical for the Sun. The physical origin of this line asymmetry is not fully understood; though, it should depend on the depth dependence of the source of wave excitation (convective turbulence) and details of the observable (velocity or intensity). For oscillations of the Sun, it has been shown that neglecting the asymmetry leads to systematic errors in the frequency determination. This could subsequently affect the results of seismic inferences of the solar internal structure. Using light curves from the Kepler spacecraft, we have measured mode asymmetries in 43 stars. We confirm that neglecting the asymmetry leads to systematic errors that
can exceed the 1σ confidence intervals for seismic observations longer than one year. Therefore, the application of an asymmetric Lorentzian profile should be favored to improve the accuracy of the internal stellar structure and stellar fundamental parameters. We also show that the asymmetry changes sign between cool Sun-like stars and hotter stars. This provides the best constraints to date on the location of the excitation sources across the Hertzsprung–Russel diagram. [O. Benomar, M. Goupil, K. Belkacem, T. Appourchaux, M. B. Nielsen, M. Bazot, L. Gizon, S. Hanasoge, K. R. Sreenivasan and B. Marchand]

Iterative inversion of synthetic travel times successful at recovering sub-surface profiles of supergranules

We develop a helioseismic inversion algorithm that can be used to recover sub-surface vertical profiles of 2-dimensional supergranular flows from surface measurements of synthetic wave travel times. We carry out seismic wave-propagation simulations through a two-dimensional section of a flow profile that resembles an averaged supergranule, and a starting model that has flows only at the surface. We assume that the wave measurements are entirely without realization noise for the purpose of our test. We expand the vertical profile of the supergranule stream function on a basis of B-splines. We iteratively update the B-spline coefficients of the supergranule model to reduce the travel-times differences observed between the two simulations. We carry out the exercise for four different vertical profiles peaking at different depths below the solar surface. We are able to accurately recover depth profiles of four supergranule models at depths up to 8–10 Mm below the solar surface using f – p4 modes, under the assumption that there is no realization noise. We are able to obtain the peak depth and the depth of the return flow for each model. A basis-resolved inversion performs significantly better than one where the flow field is inverted for at each point in the radial grid. This is an encouraging result and might act as a guide in developing more realistic inversion strategies that can be applied to supergranular flows in the Sun. [J. Bhattacharya, S. M. Hanasoge, A. C. Birch and L. Gizon]

Finite-frequency sensitivity kernels in spherical geometry for time-distance helioseismology

The inference of internal properties of the Sun from surface measurements of wave travel times is the goal of time-distance helioseismology. A critical step toward the accurate interpretation of travel-time shifts is the computation of sensitivity functions linking seismic measurements to internal structure. Here we calculate finite-frequency sensitivity kernels in spherical geometry for two-point travel-time measurements. We numerically build Green’s function by solving for it at each frequency and spherical-harmonic degree and summing over all these pieces. These computations are performed in parallel, thereby achieving significant speedup in wall-clock time. Kernels are calculated by invoking the first-Born approximation connecting deviations in the wavefield to perturbations in the operator. Validated flow kernels are shown to produce travel-times within 0.47% of the true value for uniform flows up to 750 m/s. We find that travel-time can be obtained with errors of 1 millisecond or less for flows having magnitudes similar to meridional circulation. Alongside flows, we also compute and validate sensitivity kernel for sound-speed perturbations. These accurate sensitivity kernels might improve the current inferences of sub-surface flows significantly. [K. Mandal, J. Bhattacharya, S. Halder and S. M. Hanasoge]

Numerical analysis of the lattice Boltzmann method for simulation of linear acoustic waves

We analyse a linear lattice Boltzmann (LB) formulation for simulation of linear acoustic wave propagation in heterogeneous media. We employ the single-relaxation-time Bhatnagar-Gross-Krook (BGK) as well as the general multi-relaxation-time (MRT) collision operators. By calculating the dispersion relation for various 2D lattices, we show that the D2Q5 lattice is the most suitable model for the linear acoustic problem. We also implement a grid-refinement algorithm for the LB scheme to simulate waves propagating in a heterogeneous medium with velocity contrasts. Our results show that LB performs slightly better than the classical second-order finite-difference schemes. Given its efficiency for parallel computation, the LB method can be a cost effective tool for the simulation of linear acoustic waves in complex geometries and multiphase media. [D. Dhuri, S. M. Hanasoge, P. Perlekar and J. Robertsson]

Sensitivity of helioseismic measurements of normal-mode coupling to flows and sound-speed perturbations

In this article, we derive and compute the sensitivity of measurements of coupling between normal modes of
oscillation in the Sun to underlying flows. The theory is based on first-Born perturbation theory, and the analysis is carried out using the formalism described by Lavelle & Ritzwoller (1992). Albeit tedious, we detail the derivation and compute the sensitivity of specific pairs of coupled normal modes to anomalies in the interior. Indeed, these kernels are critical for the accurate inference of convective flow amplitudes and large-scale circulations in the solar interior. We resolve some inconsistencies in the derivation of Lavelle & Ritzwoller (1992) and reformulate the fluid-continuity condition. We also derive and compute sound-speed kernels, paving the way for inverting for thermal anomalies alongside flows. [S. M. Hanasoge, M. Woodard, H. M. Antia, L. Gizon and K. R. Sreenivasan]

Sensitivity of normal-mode coupling to Lorentz stresses in the Sun

Understanding the governing mechanism of solar magnetism remains an outstanding challenge in astrophysics. Seismology is the most compelling technique with which to infer the internal properties of the Sun and stars. Waves in the Sun, nominally acoustic, are sensitive to the emergence and cyclical strengthening of magnetic field, evidenced by measured changes in resonant oscillation frequencies that are correlated with the solar cycle. The inference of internal Lorentz stresses from these measurements has the potential to significantly advance our appreciation of the dynamo. Indeed, seismological inverse theory for the Sun is well understood for perturbations in composition, thermal structure and flows but is not fully developed for magnetism, owing to the complexity of the ideal magnetohydrodynamic (MHD) equation. Invoking first-Born perturbation theory to characterize departures from spherically symmetric hydrostatic models of the Sun and applying the notation of generalized spherical harmonics, we calculate sensitivity functions of seismic measurements to the general time-varying Lorentz stress tensor. We find that eigen-states of isotropic (i.e. acoustic only) background models are dominantly sensitive to isotropic deviations in the stress tensor and much more weakly so to anisotropic stresses (and therefore challenging to infer). The apple cannot fall far from the tree. [S. M. Hanasoge]

A new length scale, and Einstein-Cartan-Dirac equations for a point mass

We have recently proposed a new action principle for combining Einstein equations and the Dirac equation for a point mass. We used a length scale, dubbed the Compton-Schwarzschild length, to which the Compton wavelength and Schwarzschild radius are small mass and large mass approximations, respectively. We then constructed the field equations which follow from this action. We argued that the large mass limit yields Einstein equations, provided we assume wave function collapse and localisation for large masses. The small mass limit yields the Dirac equation. We explained why the Kerr-Newman black hole has the same gyromagnetic ratio as the Dirac electron, both being twice the classical value. The small mass limit also provides compelling reasons for introducing torsion, which is sourced by the spin density of the Dirac field. There is thus a symmetry between torsion and gravity: torsion couples to quantum objects through Planck's constant (but not G) and is important in the microscopic limit. Whereas gravity couples to classical matter, as usual, through Newton’s gravitational constant G (but not Planck's constant?), and is important in the macroscopic limit. We constructed the Einstein-Cartan-Dirac equations which include the new length. We found a potentially significant change in the coupling constant of the torsion driven cubic non-linear self-interaction term in the Dirac-Hehl-Datta equation. We speculated on the possibility that gravity is not a fundamental interaction, but emerges as a consequence of wave function collapse, and that the gravitational constant maybe expressible in terms of Planck's constant and the parameters of dynamical collapse models. [T. P. Singh]

Einstein-Cartan-Dirac equations in the Newman-Penrose formalism

The Dirac equation on a non-torsional space-time has been studied extensively in the Newman-Penrose (NP) formalism. In particular, a comprehensive treatment is given by Chandrasekhar in his book ‘The Mathematical Theory of Black Holes’, which we take as our primary source. Building upon this work, we (working always in the NP formalism) explicitly wrote the contortion spin coefficients in terms of the Dirac spinor components. We then generalised the Dirac equations by carrying them into a torsional space-time -where it is known in this form as the Hehl-Datta equation - as permitted by the Einstein-Cartan-Sciama-Kibble (ECSK) framework which has non-vanishing torsion. Finally, we wrote down the full Einstein-Cartan-Dirac (ECD) equations in the NP formalism, and provided a solution (on Minkowski background) in various specific cases. In
particular, we demonstrated how torsion physically changes the solutions of the torsion-free Dirac equations. [Swanand Khanapurkar (IISER, Pune), Abhinav Varma (UCL, London), Nehal Mittal (IIT, Bombay), Navya Gupta (IIT, Kanpur) and T. P. Singh]

**Non-relativistic limit of Einstein-Cartan-Dirac equations**

We derived the Schrodinger-Newton equation as the non-relativistic limit of the Einstein-Dirac equations. Our analysis relaxes the assumption of spherical symmetry, made in earlier work in the literature, while deriving this limit. Since the spin of the Dirac field couples naturally to torsion, we generalized our analysis to the Einstein-Cartan-Dirac (ECD) equations, again recovering the Schrodinger-Newton equation. We then considered the ECD equations with a new length scale that unifies Compton wavelength and Schwarzschild radius, and found a Poisson equation with a modified coupling constant, in the small mass limit. [Swanand Khanapurkar (IISER, Pune), Arnab Pradhan (IIT, Madras), Vedant Dhruv (NIT, Suratkal) and T. P. Singh]

**A duality between curvature and torsion**

Compton wavelength and Schwarzschild radius were considered as limiting cases of a unified length scale. Using this length, it was shown that the Dirac equation and the Einstein equations for a point mass are limiting cases of an underlying theory which includes torsion. We showed that in this underlying theory the gravitational interaction between small masses is weaker than in Newtonian gravity. We explained as to why the Kerr-Newman black hole and the electron both have the same non-classical gyromagnetic ratio. We proposed a duality between curvature and torsion and showed that general relativity and teleparallel gravity are respectively the large mass and small mass limit of the ECSK theory. We demonstrated that small scale effects of torsion can be tested with current technology. [Swanand Khanapurkar (IISER, Pune) and T. P. Singh]

**Solving post-Newtonian accurate Kepler equation**

We provided an elegant way of solving analytically the third post-Newtonian (3PN) accurate Kepler equation, associated with the 3PN-accurate generalized quasi-Keplerian parametrization for compact binaries in eccentric orbits. An additional analytic solution was obtained to check the correctness of our compact solution and we performed various comparisons between our PN-accurate analytic solution and a very accurate numerical solution of the PN-accurate Kepler equation. We adapted our approach to compute crucial 3PN-accurate inputs that will be required to compute analytically both the time and frequency domain ready-to-use amplitude-corrected PN-accurate search templates for compact binaries in inspiralling eccentric orbits. Additionally, these expressions will be required to compute certain theoretical constructs relevant to analyze Pulsar Timing Array data sets. [Y. Boetzel, A. Susobhanan, A. Gopakumar, A. Klein and P. Jetzer]

**Polarization and Spectral Energy Distribution in OJ287 during the 2016/17 Outbursts**

We reported optical photometric and polarimetric observations of the blazar OJ287 gathered during 2016/17. The high level of activity, noticed after the General Relativity Centenary flare, was argued to be part of the follow-up flares that exhibited high levels of polarization and originated in the primary black hole jet. We proposed that the follow-up flares were induced as a result of accretion disk perturbations, traveling from the site of impact towards the primary massive black hole. The timings inferred from our observations allowed us to estimate the propagation speed of these perturbations. Additionally, we tried to make predictions for the future brightness of OJ287. [M. Valtonen, S. Zola, H. Jermak, S. Ciprini, R. Hadec, L. Dey, A. Gopakumar, et al.]

**Dipole radiation test**

We devised a way to constrain the presence of possible dipole GW contributions in observed GW events. This effort was influenced by an investigation that tried to constrain the rate of scalar black hole hair growth at the redshift of ~0.3 using the existing optical observations of a blazar OJ287, modeled to contain a massive BH binary central engine (arXiv:1111.4009). This effort resulted in a LSC-reviewed, standard Testing GR pipeline for constraining -1PN effects from the observations of a number of GW events during 2017. [M. Haney, A. Gopakumar, et al.]
X-ray Astronomy

LAXPC instrument

The Large Area X-ray Proportional Counter (LAXPC) payload on board the first Indian astronomy satellite AstroSat has been functioning for the last two and half years. This payload consists of three detectors. One of these detector developed a leak soon after launch and was switched off on March 8, 2018, when the gas pressure in the detector had reduced to about 5% of its original value. The software for reduction of level-1 data was written and is being used to analyse all data. During this year 436 different observations were carried out with LAXPC instrument, which includes both the guaranteed time proposals from AstroSat instrument teams as well as the open proposals from other astronomers from India and abroad. Since October 2017 a fraction of AstroSat time is available to international astronomy community.

Calibration of LAXPC detectors was done using radioactive sources on ground and observations of standard astronomical sources after launch. The detectors are filled with a mixture of xenon and methane gas at a pressure of about 2 atmosphere, which make them sensitive to X-rays with energy of 3–80 keV. The energy resolution and peak channel to energy mapping were obtained from calibration on ground using radioactive sources coupled with GEANT4 simulations of the detectors. The response matrix calculated using GEANT4 simulations of detectors was further refined from observations of the Crab source after launch. The effective area of detectors was estimated by comparing LAXPC data with simultaneous observation of Crab from NuSTAR. At around 20 keV the energy resolution of detectors is 10–15%, while the combined effective area of the 3 detectors is about 6000 square cm. The field of view of the detectors which is determined by the collimator is about 0.8 degree. The dead-time of the detectors is about 4 micro sec. The three detectors are independent and in the event analysis mode, they record the arrival time and energy of each photon that is detected. Because of the large size and high pressure the background is rather high at about 200 counts/sec. The variation of background during the orbit is modelled using blank sky observations and frequent blank sky observations are used to study its long term temporal variation. The LAXPC software attempts to produce a background model for each observation, though it is not always possible to take care of all variations. This limits the sensitivity of LAXPC for faint sources to about 1 mCrab. [H. M. Antia, J. S. Yadav, P. C. Agrawal, Jai Verdhaj Chauhan, R. K. Manchanda, Varsha Chitnis, B. Paul, D. Dedhia, P. B. Shah, V. M. Gujar, T. Katoch, V. N. Kurhade, P. Madhwani, T. K. Manojkumar, V. A. Nikam, A. S. Pandya, J. V. Parmar, D. M. Pawar, M. Pahari, R. Misra, K. H. Navalgund, R. Pandiyani, K. S. Sharma and K. Subbarao]

The low-mass X-ray binary 4U 1728-24 was observed with AstroSat/LAXPC on March 8, 2016. The source intensity was nearly steady but, toward the end of the observation, a typical Type-1 burst was detected. Dynamical power spectrum of the data in the 3–20 keV band, revealed the presence of a kHz Quasi-Periodic Oscillation (QPO) for which the frequency drifted from about 815 Hz at the beginning of the observation to about 850 Hz just before the burst. The QPO is also detected in the 10–20 keV band, which was not seen by earlier RXTE observations of this source. Even for such a short observation with a drifting QPO frequency, the time lag between the 5–10 and 10–20 keV bands can be constrained to be less than 100 microseconds. The Type-1 burst that lasted for about 20 s had a typical profile. During the first four seconds, dynamic power spectra reveal a burst oscillation for which the frequency increased from 361.5 to 363.5 Hz. This is consistent with the earlier results obtained with RXTE/PCA, showing the same spin frequency of the neutron star. The present results demonstrate the capability of the LAXPC instrument for detecting millisecond variability even from short observations. [Jai Verdhaj Chauhan, J. S. Yadav, R. Misra, P. C. Agrawal, H. M. Antia, M. Pahari, N. Sridhar, D. Dedhia, T. Katoch, P. Madhwani, R. K. Manchanda, B. Paul and P. B. Shah]

The X-ray binary Cyg X-3 was observed by AstroSat/LAXPC several times over one year of AstroSat operation. Consecutive light curves observed over a period of one year show the binary orbital period of 17253.56 ± 0.19 s. Another low-amplitude, slow periodicity of the order of 35.8 ± 1.4 days is observed, which may be due to the orbital precession as suggested earlier. During the rising binary phase, power density spectra from different observations during the flaring

Department of Astronomy and Astrophysics 29
hard X-ray state show quasi-periodic oscillations (QPOs) at 5–8 mHz, 12-14 mHz, and 18–24 mHz frequencies at the minimum confidence of 99%. However, during the consecutive binary decay phase, no QPO is detected up to 2 sigma significance. Energy-dependent time-lag spectra show soft lag (soft photons lag hard photons) at the mHz QPO frequency and the fractional rms of the QPO increases with the photon energy. During the binary motion, the observation of mHz QPOs during the rising phase of the flaring hard state may be linked to the increase in the supply of the accreting material in the disk and corona via stellar wind from the companion star. During the decay phase, the compact source moves in the outer wind region causing the decrease in supply of material for accretion. This may cause weakening of the mHz QPOs below the detection limit. This is also consistent with the preliminary analysis of the orbital phase-resolved energy spectra. [M. Pahari, H. M. Antia, J. S. Yadav, Jai Verdhan Chauhan, P. C. Agrawal, R. Misra, V. R. Chitnis, D. Dedhia, T. Katoch, P. Madhwani, R. K. Manchanda, B. Paul and P. B. Shah]

Distinguishing Kerr naked singularities and black holes using the spin precession of a test gyro in strong gravitational fields

Sudip Bhattacharyya and his collaborators studied the precession of the spin of a test gyrooscope attached to a stationary observer in the Kerr spacetime, specifically, to distinguish a naked singularity (NS) from a black hole (BH). For such gyros, the precession frequencies diverge on the event horizon of a BH, but are finite and regular for an NS everywhere except at the singularity itself. They then investigated the Lense-Thirring (LT) precession or nodal plane precession frequency of the accretion disk around a BH and an NS to show that clear distinctions exist for these configurations in terms of radial variation features. There are important differences in accretion disk LT frequencies for a BH and an NS, and since LT frequencies are intimately related to observed quasiperiodic oscillations, these features might allow one to determine whether a given rotating compact astrophysical object is a BH or a NS. [Sudip Bhattacharyya, Chandrachur Chakraborty, Prashant Koehlerlakota, Mandar Patil, Pankaj S. Joshi and Andrzej Krolak]

Millisecond radio pulsars with known masses: parameter values and equation of state models

The recent fast growth of a population of millisecond pulsars with precisely measured mass provides an excellent opportunity to characterize these compact stars at an unprecedented level. This is because the stellar parameter values can be accurately computed for known mass and spin rate and an assumed equation of state (EoS) model. For each of the 16 such pulsars and for a set of EoS models from nucleonic, hyperonic, strange quark matter and hybrid classes, Sudip Bhattacharyya and his collaborators numerically computed fast spinning stable stellar parameter values considering the full effect of general relativity. This first detailed catalogue of the computed parameter values of observed millisecond pulsars provided a testbed to probe the physics of compact stars, including their formation, evolution and EoS. They estimated uncertainties on these computed values from the uncertainty of the measured mass, which could be useful to quantitatively constrain EoS models. They noted that the largest value of the central density in their catalogue is ~5.8 times the nuclear saturation density, which is much less than the expected maximum value (which is 13 times the nuclear saturation density). They also found that the constraints on EoS models from accurate radius measurements could be significantly biased for some of our pulsars, if stellar spinning configurations are not used to compute the theoretical radius values. [Sudip Bhattacharyya, Ignazio Bombaci, Debades Bandyopadhyay, Arun V. Thampan and Domenico Logoteta]

A tilted and warped inner accretion disk around a spinning black hole: an analytical solution

Inner accretion disk around a black hole provides a rare, natural probe to understand the fundamental physics of the strong gravity regime. A possible tilt of such a disk, with respect to the black hole spin equator, is important. This is because such a tilt affects the observed spectral and timing properties of the disk X-ray emission via Lense-Thirring precession, which could be used to test the theoretical predictions regarding the strong gravity. Sudip Bhattacharyya and his collaborator analytically solved the steady, warped accretion disk equation of Scheuer and Feier, and found an expression of the radial profile of the disk tilt angle. In their exact solution, considering a prograde disk around a slowly spinning black hole, they included the inner part of the disk, which was not done earlier in this formalism. Such a solution was timely, as a tilted inner disk had been inferred from X-ray spectral and timing features of the accreting black hole H1743-322.
Their tilt angle radial profile expression included observationally measurable parameters, such as black hole mass and Kerr parameter, and the disk inner edge tilt angle, and hence could be ideal to confront observations. Their solution showed that the disk tilt angle in 10–100 gravitational radii is a significant fraction of the disk outer edge tilt angle. [Sudip Bhattacharyya and Chandrachur Chakraborty]

Application of a new method to study the spin equilibrium of Aql X-1: the possibility of gravitational radiation

Accretion via disks can make neutron stars in low-mass X-ray binaries (LMXBs) fast spinning, and some of these stars are detected as millisecond pulsars. Sudip Bhattacharyya reported a practical way to find out if a neutron star in a transient LMXB has reached the spin equilibrium by disk-magnetosphere interaction alone, and if not, to estimate this spin equilibrium frequency. These can be done using specific measurable source luminosities, such as the luminosity corresponding to the transition between the accretion and propeller phases, and the known stellar spin rate. Such a finding could be useful to test if the spin distribution of millisecond pulsars, as well as an observed upper cutoff of their spin rates, can be explained using disk-magnetosphere interaction alone, or additional spin-down mechanisms, such as gravitational radiation, are required. Applying his method, Sudip Bhattacharyya found that the neutron star in the transient LMXB Aql X-1 has not yet reached the spin equilibrium by disk-magnetosphere interaction alone. Prof. Bhattacharyya also performed numerical computations, with and without gravitational radiation, to study the spin evolution of Aql X-1 through a series of outbursts and to constrain its properties. While he found that the gravitational wave emission from Aql X-1 cannot be established with certainty, his numerical results showed that the gravitational radiation from Aql X-1 is possible.

Two coexisting families of compact stars: observational implications for millisecond pulsars

It is usually thought that a single equation of state (EoS) model “correctly” represents cores of all compact stars. Sudip Bhattacharyya and his collaborators emphasized that two families of compact stars, viz., neutron stars and strange stars, can coexist in nature, and that neutron stars can get converted to strange stars through the nucleation process of quark matter in the stellar center. From the fully general relativistic numerical computations of the structures of fast-spinning compact stars, known as millisecond pulsars, they found that such a stellar conversion causes a simultaneous spin-up and decrease in gravitational mass of these stars. This is a new type of millisecond pulsar evolution through a new mechanism, which gives rise to relatively lower mass compact stars with higher spin rates. This could have an implication for the observed mass and spin distributions of millisecond pulsars. Such a stellar conversion can also rescue some massive, spin-supported millisecond pulsars from collapsing into black holes. Besides, Prof. Bhattacharyya and his collaborators pointed out that neutron star EoS models cannot be ruled out by the stellar mass measurement alone. Finally, they emphasized the additional complexity for constraining EoS models, for example, by stellar radius measurements using X-ray observations, if two families of compact stars coexist. [Sudip Bhattacharyya, Ignazio Bombaci, Domenico Logoteta and Arun V. Thampan]

A Precise Measurement of the Orbital Period Parameters of Cygnus X-3

Sudip Bhattacharyya and his collaborators presented X-ray light curves of Cygnus X-3 as measured by the AstroSat satellite. The light curve folded over the binary period of 4.8 hr shows a remarkable stability over the past 45 years and they found that they could use this information to measure the zero point to better than 100 s. They revisited the historical binary phase measurements and examined the stability of the binary period over 45 years. They presented a new binary ephemeris with the period and period derivative determined to an accuracy much better than previously reported. They did not find any evidence for a second derivative in the period variation. The precise binary period measurements, however, indicated a hint of short-term episodic variations in periods. Interestingly, these short-term period variations coincided with the period of enhanced jet activity exhibited by the source. Prof. Bhattacharyya and his collaborators discussed the implications of these observations on the nature of the binary system. [Sudip Bhattacharyya, Yash Bhargava, A. R. Rao, K. P. Singh, Manojendu Choudhury, S. Chandra, G. C. Dewangan, K. Mukerjee, G. C. Stewart, D. Bhattacharya, N. P. S. Mithun and S. V. Vadawale]

Extensive broadband X-ray monitoring during the formation of a giant radio jet base in Cyg X-3 with AstroSat
Sudip Bhattacharyya and his collaborators presented X-ray spectral and timing behavior of Cyg X-3 as observed with AstroSat during the onset of a giant radio flare on 2017 April 1–2. Within a timescale of a few hours, the source showed a transition from the hypersonic state (HPS) to a more luminous state (they termed as the very high state), which coincided with the time of the steep rise in radio flux density by an order of magnitude. Modeling the Soft X-ray Telescope (SXT) and Large Area X-ray Proportional Counter (LAXPC) spectra jointly in 0.5–70.0 keV, they found that the first few hours of the observation is dominated by the HPS with no significant counts above 17 keV. Later, an additional flat power-law component suddenly appeared in the spectra that extended to very high energies with the power-law photon index of 1.49. Such a flat power-law component was never reported from Cyg X-3. Interestingly the fitted power-law model in 25-70 keV, when extrapolated to the radio frequency, predicted the radio flux density to be consistent with the trend measured from the RATAN-600 telescope at 11.2 GHz. This provided direct evidence of the synchrotron origin of flat X-ray power-law component and the most extensive monitoring of the broadband X-ray behavior at the moment of decoupling the giant radio jet base from the compact object in Cyg X-3. Using SXT and LAXPC observations, Prof. Bhattacharyya and his collaborators determined the giant flare ejection time as MJD 57845.34, when 11.2 GHz radio flux density increased from ~100 to ~478 mJy. [Sudip Bhattacharyya, Mayukh Pahari, J. S. Yadav, Jai Verdhan Chauhan, Divya Rawat, Ranjeev Misra, P. C. Agrawal, Sunil Chandra, Kalyani Bagri, Pankaj Jain, R. K. Manchanda and Varsha Chitnis]

Cadmium Zinc Telluride Imager (CZT) of AstroSat

The Cadmium Zinc Telluride Imager (CZTI) is one of the five instruments onboard AstroSat, India’s first multi-wavelength astronomy satellite, launched on 2015 September 28. Regular proposal based observations were carried out using the AstroSat satellite. The CZTI instrument has some unique capabilities like all sky monitoring and hard X-ray polarisation capability. CZTI regularly identifies new gamma-ray bursts (GRBs). GRB Coordination Network (GCN) circulars are regularly sent alerting the GRB community about the detection of GRBs by CZTI. CZTI is proving to be a sensitive monitor to search for the counter parts of Gravitational Wave (GW) events. An interesting variation in the polarisation properties in the Crab Nebula, when examined as a function of its pulse phase, was discovered using CZTI. Spectro-polarimetric studies were carried out for several GRBs.

As a part of the Payload Operation activity of CZTI, various important parameters of the instrument were regularly monitored and a Health history of the instrument was maintained. The parameters that are monitored on monthly basis are various voltages, CZT-HV, Veto-HV, Veto LLD, CPM counts, Quadrant and Detector temperatures. A monthly average of these values are stored to check for any noticeable changes in these values over the course of time. History of bad pixels are also maintained for every orbit. Decision of suppression of noisy pixel depends on the percentage of time for which a particular pixel was noisy. All these values are shown in a Mysql database.

The Qualification Model (QM) of CZTI is kept operational in the laboratory. It was tested on a regular basis to check its performance. It is also used for performing various tests for better understanding of Polarization in CZT modules. The double pixel events arising from the Compton scattering of a photon in one pixel and absorption of the scattered photon in another pixel constitute the basic polarization event. Radioactive sources like Ba133 source are used to study Polarization with CZTI at different polarization angles. [A. R. Rao, M. K. Hingar, A. P. K. Kutty, M. H. Patil, Ajay Ratheesh, V. Chand, along with the Avionics Group, VSSC, Thiruvananthapuram, IUCAA, Pune, and PRL, Ahmedabad]

Instrumentation for future Space Programs

Proportional counters are widely used in X-ray astronomy due to better efficiency. Our new proposed Low Weight Proportional Counter (LWPC) design with 2000 cm² effective area (weight about 5 kg, including all electronics), will provide an extremely low weight proportional counter assembly by offering Mass To Area Ratio (MTAR) 2.5 gm per cm² in the 2 – 10 keV energy band, and can be used at higher energies with some weight penalty for shielding. This may be compared with 20 gm/cm² for the PPC onboard IXAE (2 – 10 keV), 50 gm/cm² for LAXPC (3 – 80 keV), 50 gm/cm² for CZTI (10 – 100 keV), 10 gm/cm² for LOFT using silicon detectors (2 – 30 keV). Thus, an order of magnitude improvement in MTAR as compared to earlier missions was achieved. This weight is even superior to the futuristic LOFT mission, at a
significantly lower cost. The basic design was completed for LWPC. [A. R. Rao, M. K. Hingar, A. P. K. Kutty, M. H. Patil and Ajay Ratheesh]

**Luminosity function of Gamma-ray Bursts.**

Gamma-ray bursts (GRBs) are astrophysical transients associated with the collapse of a massive star into a black hole – ‘long GRBs’; and the merger of neutron star binaries to form a more massive neutron star or a low-mass black hole along with the emission of gravitational waves – ‘short GRBs’. It is important to make statistical inferences of these two populations of GRBs, and to estimate their true rate in the universe. The ‘luminosity function’ of both the long and short GRBs, which is the probability density function over the intrinsic parameter of the bursts, the luminosity was carefully studied. The most updated data from the existing GRB catalogues of Swift-BAT, Fermi-GBM and CGRO-BATSE were used for this purpose. It was shown that the claim of using long GRBs as distance-indicators in the high redshift universe is misled, as well as the measurement of redshifts of short GRBs are heavily affected by selection bias. However, in both cases, the consistency of the method is demonstrated and constraints put on two models of the luminosity function. These models are then used to calculate the true rate of GRBs and predictions are made for the number of bursts detectable by AstroSat-CZTI, then tallied against observations. It was shown that the scenario that each binary neutron star merger (BNSM) produces a short GRB, cannot be ruled out. Using the maximum distance to which the gravitational networks are sensitive in the past, present and future runs, stringent lower limits were placed on the detectable BNSM rate. In light of the detection of GW/EM170817, which is consistent with these predictions, it was shown that the number will go up significantly in the next observing runs of LIGO/VIRGO. [D. Paul]

**Infrared Astronomy**

**Instrumentation**

**TIFR Near-Infrared Imaging Camera-II (TIRCAM2) for 3.6-meter Devasthal Optical Telescope (DOT)**

TIRCAM2 is a closed-cycle Helium cryo-cooled imaging camera equipped with a Raytheon 512×512 pixels InSb Aladdin III Quadrant focal plane array having sensitivity to photons in the 1–5 μm wavelength band. We presented the performance of the camera on the newly installed 3.6-meter Devasthal Optical Telescope (DOT) based on the calibration observations carried out during 2017 May 11–14 and 2017 October 7–31. After the preliminary characterization, the camera has been released to the Indian and Belgian astronomical community for science observations since 2017 May. The camera offers a field-of-view of ~86.5 arcsec × 86.5 arcsec on the DOT with a pixel scale of 0.169 arcsec. The seeing at the telescope site in the near-infrared (NIR) bands is typically sub-arcsecond with the best seeing of ~0.45 arcsec realized in the NIR K-band on 2017 October 16. The camera is found to be capable of deep observations in the J, H and K bands comparable to other 4-meter class telescopes available world-wide. Another highlight of this camera is the observational capability for sources up to Wide-field Infrared Survey Explorer (WISE) W1-band (3.4 μm) magnitudes of 9.2 in the narrow L-band (nbL; λcen ~ 3.59 μm). Hence, the camera could be a good complementary instrument to observe the bright nbL-band sources that are saturated in the Spitzer-Infrared Array Camera ([3.6] ≤ 7.92 mag) and the WISE W1-band ([3.4] ≤ 8.1 mag). Sources with strong polycyclic aromatic hydrocarbon emission at 3.3 μm are also detected. A three-color composite image (red: K-band, green: H-band, blue: J-band) of the globular cluster M92, constructed using the TIRCAM2 JHK bands, is presented in the figure below. [D. K. Ojha, S. K. Ghosh, T. Baug (KIAA, China), J. P. Ninan (PSU, USA), M. B. Naik, S. S. Poojary, S. B. Bhagat, R. B. Jadhav, S. L. A. D’Costa, G. S. Meshram, H. Shah, P. R. Sandimani, B. G. Bagade, S. M. Gharat, C. B. Bakalkar, S. Sharma, A. K. Pandey, B. Kumar and A. Ghosh (ARIES, Nainital)]

The color-composite image (red: K-band, green: H-band, blue: J-band) of M92, a Galactic globular cluster, constructed using the frames observed with the TIRCAM2 attached to the 3.6m DOT (left). A color-composite image for the same area generated using the 2MASS J, H, and K band images is also shown (right) for comparison.

TIFR Near-Infrared Spectrometer and Imager (TIRSPEC) for 2-meter Himalayan Chandra Telescope (HCT)

TIRSPEC is still being heavily used on 2-meter HCT at Hanle (Ladakh) for studies of Galactic and extragalactic sources like star-forming regions, supernovae, novae, active galactic nuclei, etc in the 1–2.5 µm near-infrared band. TIRSPEC will be due for an upgrade of the detector system in the near future. A number of science papers using TIRSPEC data have been published in various peer-reviewed refereed journals during the past one year. [D. K. Ojha, S. K. Ghosh, J. P. Ninan (PSU, USA), S. L. A. D’Costa, M. B. Naik, P. R. Sandimani, S. S. Poojary, S. B. Bhagat, R. B. Jadhav, G. S. Meshram, S. M. Gharat and C. B. Bakalkar]

InfraRed Spectroscopic Imaging Survey (IRSIS) Satellite Payload

The report on the Laboratory Model of the IRSIS satellite payload has been completed and work on the design and fabrication of the long-wavelength channel is in an advance stage. A detailed report on the performance of the IRSIS Laboratory Model has already been submitted to ISRO (Space Science Office) for the further approval. [S. K. Ghosh, D. K. Ojha, M. Puravankara, S. L. A. D’Costa, M. B. Naik, P. R. Sandimani, S. S. Poojary, S. B. Bhagat, R. B. Jadhav, G. S. Meshram, S. M. Gharat and C. B. Bakalkar]

Mid-Infrared IFU Spectroscopy Satellite (MISS) for the L2 Orbit

In reply to the announcement of opportunities by ISRO for future astronomical space payloads, we have proposed to build a mid-infrared (mid-IR) integral field unit (IFU) spectrograph (MISS) to be placed in the L2 (Sun-Earth second Lagrange point) orbit to map the star-forming regions. The objective is to conduct a comprehensive mid-IR spectroscopic survey of selected star-forming regions to study the evolution of protostars, protoplanetary discs, circumstellar environment, as well as the interstellar medium (ISM). Our preliminary concept design is a passively cooled multi-object IFU spectrograph of resolution R~1000 in the 2.5 to 5 µm wavelength range, with a possible extension to do spectro-polarimetry, without any moving parts. Even though this mission will be competitive by itself, we also plan this design as a path finder for an actively cooled future larger L2 mission which does spectro-polarimetry of interstellar grains at 10 µm wavelength in protoplanetary discs and ISM. We have provided the concept designs of both spectrographs. [D. K. Ojha, S. K. Ghosh, J. P. Ninan (PSU, USA), M. Puravankara, B. Mookerjea, S. L. A. D’Costa, M. B. Naik, P. R. Sandimani, S. S. Poojary, P. B. Shah, D. K. Dedhia, P. P. Madhvani, H. Shah, S. B. Bhagat, R. B. Jadhav, G. S. Meshram, S. M. Gharat, C. B. Bakalkar and B. G. Bagade]

TIFR-ARIES Near-Infrared Spectrometer (TANSPEC) for 3.6-meter Devasthal Optical Telescope (DOT)

The fabrication of TANSPEC for 3.6-meter DOT is completed. The premilinary cold runs of TANSPEC in the lab have been carried out successfully and the final calibration cold run will be carried out in the near future. TANSPEC will be shipped to 3.6m DOT in the coming months. It will then be used for the sky
Multi-Object Infrared Spectrometer (MOIS) for the National Large Optical/IR Telescope

The preliminary designs of the MOIS are ready and many of the sub-systems like movable slits, detector control system and optical designs are in an advance stage of design and testing. The MOIS is being designed for the 3.6m DOT with the aim of having a working design of a wide-field multi-object near-infrared spectrograph for the proposed national large optical/IR telescope. [M. Puravankara, B. Mookerjea, D. K. Ojha, S. K. Ghosh, M. Narang, S. L. A. D’Costa, S. S. Poojary, H. Shah, P. R. Sandimani, S. B. Bhagat, R. B. Jadhav, G. S. Meshram, S. M. Gharat, C. B. Bakalkar, S. Sharma and A. K. Pandey (ARIES, Nainital)]

Balloon-borne Far Infrared Astronomy

The TIFR 100 cm balloon borne Far Infrared telescope (T100) along with the upgraded Japanese Fabry Perot Spectrometer (FPS) tuned to astrophysically important line of [C II] at 158 µm, was launched on November 30, 2017 and March 18, 2018, from the TIFR Balloon Facility, Hyderabad, during winter 2017 and summer 2018 flight campaigns. The T100 performed as designed with a Japanese FPS at the focal plane. The performance of the FPS system is being investigated using the FIR data collected during the ~5.5 hours of float at ~31.5 km altitude. The same payload was successfully flown thrice in a span of approximately one year (February 2017, November 2017 & March 2018) which is a record for this large complex IR instrument. [S. K. Ghosh, D. K. Ojha, S. L. A. D’Costa, P. R. Sandimani, S. S. Poojary, S. B. Bhagat, G. S. Meshram, C. B. Bakalkar, R. B. Jadhav, S. M. Gharat, H. Shah, B. G. Bagade, S. Oyabu, T. Suzuki, F. Saito, T. Ishinohachi and M. Hanaoka (Nagoya University, Japan)]

Multiwavelength Study of Galactic Star Forming Regions

We presented the results of our studies of high mass star-forming regions on the scales from several parsecs to hundreds AU at wavelengths from low frequency radio band to IR. These include: G192.76+00.10, G35.673-00.847, Sh 2-53, Be 59, Sh 2-235, IRAS 05463+2652, Sh 2-242, IC 1805, IRAS 05480+2545 and NGC 7538. On large scales fragmented shells and filaments are investigated, showing signatures of induced star formation. On small scales we observe dense cores at various stages of evolution. Some of them represent rotating disks and are associated with high velocity outflows. There are signs of episodic accretion and ejection events.

Our multiwavelength data comprise of optical and near-infrared (NIR) photometric and spectroscopic observations from the 2-meter Himalayan Chandra Telescope, radio observations from the Giant Metrewave Radio Telescope (GMRT), and archival data covering radio through NIR wavelengths. Optical spectroscopic observations are used to constrain the spectral type of ionizing stars. The nature of these H II regions is characterized by estimating parameters such as electron density and emission measure, using the radio continuum observations. To understand local star formation, we identified young stellar object (YSO) candidates using grism slitless spectroscopy, NIR and mid-infrared (MIR) observations. The NIR and MIR analysis is complemented with GMRT low-frequency observations, molecular line observations of $^{13}$CO (J=1-0) & H$^{13}$CO+ (J=1-0), and archival Chandra X-ray observations. Thermal dust emission modelling, using the FIR data from Herschel and performing modified blackbody fittings, helped us construct the temperature and column density maps of the H II regions. We have suggested that multi-generation star formation is present in several star-forming complexes. The molecular outflows are detected in few subregions, further confirming the ongoing star formation activity. Together, all these results are interpreted as observational evidence of positive feedback of a massive star. Our observational findings also suggest that the star formation activities (including massive stars) appear to be influenced by the cloud-cloud collision mechanism at the junction in few star-forming regions. We also studied the spatial correlation of the YSOs with the distribution of gas and dust of the complex to conclude that IC 1805 would have formed in a large filamentary cloud. [D. K. Ojha, T. Baug (KIAA, China), J. P. Ninan (PSU, USA), S. K. Ghosh, L. K. Dewangan (PRL, Ahmedabad), S. Sharma, A. K. Pandey (ARIES, Nainital), N. Panwar (Univ. of Delhi) and I. Zinchenko (IAP, Russia)]
Filamentary infrared dark cloud G192.76+00.10 in the S254-S258 OB complex

We presented results of a high resolution study of the filamentary infrared dark cloud G192.76+00.10 in the S254-S258 OB complex in several molecular species tracing different physical conditions. These include three isotopologues of carbon monoxide (CO), ammonia (NH₃), carbon monosulfide (CS). The aim of this work was to study the general structure and kinematics of the filamentary cloud, its fragmentation and physical parameters. The gas temperature is derived from the NH₃ (J,K)=(1,1), (2,2) and ¹³CO(2-1) lines and the ¹²CO(1-0), ¹³CO(2-1) emission is used to investigate the overall gas distribution and kinematics. Several dense clumps are identified from the CS(2-1) data. Values of the gas temperature lie in the ranges 10−35 K, column density N(H₂) reaches the value 5.1x10²² cm⁻². The width of the filament is of order 1 pc. The masses of the dense clumps range from ~30 Mₒ to ~160 Mₒ. They appear to be gravitationally unstable. The molecular emission shows a gas dynamical coherence along the filament. The velocity pattern may indicate longitudinal collapse. [O. L. Ryabukhina, I. I. Zinchenko (Russia), M. R. Samal (Taiwan), P. M. Zemlyanukha, D. A. Ladeychikov, A. M. Sobolev (Russia), C. Henkel (Germany) and D. K. Ojha]

Mid-infrared Bubble N49 Site: A Clue of Collision of Filamentary Molecular Clouds

We investigated the star formation processes operating in a mid-infrared bubble N49 site that harbors an O-type star in its interior, an ultracompact H II region, and a 6.7 GHz methanol maser at its edges. The ¹³CO line data reveal two velocity components (at velocity peaks ~88 and ~95 km s⁻¹) in the direction of the bubble. An elongated filamentary feature (length >15 pc) is investigated in each molecular cloud component, and the bubble is found at the interface of these two filamentary molecular clouds. The Herschel temperature map traces all these structures in a temperature range of ~16–24 K. In the velocity space of ¹¹CO, the two molecular clouds are separated by ~7 km s⁻¹, and are interconnected by a lower-intensity intermediate velocity emission (i.e., a broad bridge feature). A possible complementary molecular pair at [87, 88] km s⁻¹ and [95, 96] km s⁻¹ is also observed in the velocity channel maps. These observational signatures are in agreement with the outcomes of simulations of the cloud–cloud collision process. There are also noticeable embedded protostars and Herschel clumps distributed toward the filamentary features including the intersection zone of the two molecular clouds. In the bubble site, different early evolutionary stages of massive star formation are also present. Together, these observational results suggest that in the bubble N49 site, the collision of the filamentary molecular clouds appears to be operated about 0.7 Myr ago, and may have triggered the formation of embedded protostars and massive stars. [L. K. Dewangan (PRL, Ahmedabad), D. K. Ojha and I. Zinchenko (Russia)]

Discovery of ¹³CCC in SgrB2(M)

Small carbon chain molecules like linear CCC are thought to play a crucial role in the formation of larger, complex molecules, including pre-biotic species. The formation pathways of organic molecules with carbon chains as backbones is by far not well understood. Studies of isotope fractionation have proven to be a useful tool of tracing chemical reaction pathways and to elucidate formation and destruction processes of interstellar molecules. Recent velocity-resolved observations in the far-infrared have resulted in the detection of CCC ro-vibrational transitions in the warm envelopes of starforming hot cores W31C, W49N and DR21(OH). Multiple far-infrared transitions of CCC have also been detected towards the Galactic center molecular clouds SgrB2(M) and SgrB2(N). Since C⁺ is involved in an important step of the formation route of the CCC molecule, it is likely that effects of isotopic fractionation of C⁺ will manifest itself in the CCC/¹³CCC and CCC/C²⁺CC ratios as well. Based on high resolution THz-laboratory measurements of CCC and its ¹³C-isotopologues conducted at the Kassel laboratories, we used the GREAT-receiver onboard SOFIA for a first ever detection of ¹³CCC towards SgrB2(M). [T. Giesen (Kassel), B. Mookerjea (TIFR), J. Stutzki (Cologne), A. A. Breier, T. Buechling and G. W. Fuchs (Kassel)]

[C I], [C II] and CO emission lines as a probe for z variations at low and high redshifts

The variability of dimensionless physical constants such as the electron-to-proton mass ratio, μ = mₑ/mₚ, and the fine structure constant, α =e²/c, remains an active area of theoretical and experimental studies. We used the offsets between the radial velocities of the rotational transitions of carbon monoxide and the fine structure transitions of neutral and singly ionized carbon to test
the hypothetical variation of the fine structure constant, \( \alpha \). From the analysis of the [C I] and [CII] fine structure lines and low J rotational lines of \(^{12}\)CO and \(^{13}\)CO, emitted by the dark cloud L1599B in the Milky Way disc, we found no evidence for fractional changes in \( \alpha \) at the level of \( |\Delta \alpha/\alpha| <3\times10^{-7} \). For the neighbouring galaxy, M33, we could put a stringent limit on \( \Delta \alpha/\alpha \) based on observations of three H II zones in [C II] and CO emission lines: \( |\Delta \alpha/\alpha| <4\times10^{-7} \). For five systems over the redshift interval \( z = 5.7–6.4 \), showing CO \( J = 6–5 \), \( J = 7–6 \) and [C II] 158 micron emission we obtained a limit on \( |\Delta \alpha/\alpha| <1.3\times10^{-5} \). Thus we showed that a combination of the [CI], [CII] and CO emission lines is a powerful tool for probing the stability of the fundamental physical constants over a wide range of redshifts not accessible to optical spectral measurements. [S. A. Levshakov (Russia), K. W. Ng (Taiwan), C. Henkel (Germany) and B. Mookerjea (TIFR)]

C II distribution around S1 in rho Ophiuchi

We studied [C II] at 158 \( \mu m \) emission from the Photon Dominated Region (PDR) associated with \( \varpi \) Oph-A using SOFIA/GREAT to obtain useful insight into the distribution of the PDR material, particularly in the nebula around the B-type star S1. The PDR around S1, is ideally suited to study the interaction between an expanding nebula and the molecular cloud. In this source a large cigar shaped cavity extends more to the east/northeast than to the west/southwest, where the expansion is blocked by the dense surrounding molecular cloud. We observed that unlike the emission from CO (and its isotopes) and to some extent [O I] the [C II] emission is completely dominated by the emission/reflection nebula illuminated by S1. This suggested that the observed [C II] emission is primarily due to the FUV radiation from S1 with a negligible contribution from the nearby B2 V star HD 147889, which illuminates the reflection nebula. The [C II] emission is significantly optically thick as over most of the nebula as evidenced by the detection of the hyperfine transition of \(^{13}\)C. The [C II] lines were observed to be strongly self-absorbed over an extended region in the S1 PDR. A two-component analysis of the [C II] spectral profile assuming Local Thermal Equilibrium was performed to derive the physical properties of the emitting nebula and the foreground cold absorbing cloud. We studied the line profiles of [C II] to understand the exact geometry of the region. We also deduced the density of the emitting PDR and the far-ultraviolet radiation field exciting it. [B. Mookerjea (TIFR), G. Sandell (Univ of Hawai), W. Vacca, E. Chambers (USRA/SOFIA) and R. Guesten (MPIfR, Bonn)]

The Curious Case of PDS 11: A Nearby, >10 Myr Old, Classical T Tauri Binary System

In this work, we presented results of our study of the PDS 11 binary system, which belongs to a rare class of isolated, high Galactic latitude T Tauri stars. Our spectroscopic analysis revealed that PDS 11 is an M2-M2 binary system with both components showing similar H\( \alpha \) emission strengths. Both the components appear to be accreting and are classical T Tauri stars. The lithium doublet Li I \( \lambda 6708 \), a signature of youth, is present in the spectrum of PDS 11A, but not in PDS 11B. From the application of lithium depletion boundary age-dating method and a comparison with the Li I 6708 angstroms equivalent width distribution of moving groups, we estimated an age of 10–15 Myr for PDS 11A. Comparison with pre-main sequence evolutionary models indicates that PDS 11A is a 0.4 M\(_{\odot}\) T Tauri star at a distance of 114–131 pc. PDS 11 system does not appear to be associated with any known star-forming regions or moving groups. PDS 11 is a new addition, after TWA 30 and LDS 5606, to the interesting class of old, dusty, wide binary classical T Tauri systems in which both components are actively accreting. [B. Mathew, P. Manoj, B. C. Bhatt, D. K. Sahu, G. Maheswar and S. Muneer]

Star Formation Under the Outflow: The Discovery of a Non-thermal Jet from OMC-2 FIR 3 and Its Relationship to the Deeply Embedded FIR 4 Protostar

We carried out multiwavelength (0.7–5 cm), multi-epoch (1994–2015) Very Large Array (VLA) observations toward the region enclosing the bright far-IR sources FIR 3 (HOPS 370) and FIR 4 (HOPS 108) in OMC-2. We report the detection of 10 radio sources, 7 of them identified as young stellar objects. We image a well-collimated radio jet with a thermal free-free core (VLA 11) associated with the Class I intermediate-mass protostar HOPS 370. The jet features several knots (VLA 12N, 12C, 12S) of non-thermal radio emission (likely synchrotron from shock-accelerated relativistic electrons) at distances of \(~7500–12,500\) au from the protostar, in a region where other shock tracers have been previously identified. These knots are moving away from the HOPS 370 protostar at \~100 km/s. The
Class 0 protostar HOPS 108, which itself is detected as an independent, kinematically decoupled radio source, falls in the path of these non-thermal radio knots. These results favor the previously proposed scenario in which the formation of HOPS 108 is triggered by the impact of the HOPS 370 outflow with a dense clump. However, HOPS 108 has a large proper motion velocity of \( \sim 30 \) km s\(^{-1}\), similar to that of other runaway stars in Orion, whose origin would be puzzling within this scenario. Alternatively, an apparent proper motion could result because of changes in the position of the centroid of the source due to blending with nearby extended emission, variations in the source shape, and/or opacity effects. [M. Osorio, A. K. Diaz-Rodriguez, G. Anglada, S. T. Megeath, L. Rodriguez, J. J. Tobin, A. M. Stutz, E. Furlan, W. J. Fischer, P. Manoj, J. F. Gomez, B. Gonzalez-Garcia et al.]

**The Herschel Orion Protostar Survey: Luminosity and Envelope Evolution**

The Herschel Orion Protostar Survey obtained well-sampled 1.2–870 micron spectral energy distributions (SEDs) of over 300 protostars in the Orion molecular clouds, home to most of the young stellar objects (YSOs) in the nearest 500 pc. We plot the bolometric luminosities and temperatures for 330 Orion YSOs, 315 of which have bolometric temperature characteristic of protostars. The histogram of the bolometric temperature is roughly flat; 29% of the protostars are in Class 0. The median luminosity decreases by a factor of four with increasing bolometric temperature; consequently, the Class 0 protostars are systematically brighter than the Class I protostars, with a median luminosity of 2.3 \( L_\odot \) as opposed to 0.87 \( L_\odot \). At a given bolometric temperature, the scatter in luminosities is three orders of magnitude. Using fits to the SEDs, we analyze how the luminosities corrected for inclination and foreground reddening relate to the mass in the inner 2500 au of the best-fit model envelopes. The histogram of the envelope mass is roughly flat, while the median-corrected luminosity peaks at 15 \( L_\odot \) for young envelopes and falls to 1.7 \( L_\odot \) for late-stage protostars with remnant envelopes. The spread in luminosity at each envelope mass is three orders of magnitude. Envelope masses that decline exponentially with time explain the flat mass histogram and the decrease in luminosity, while the formation of a range of stellar masses explains the dispersion in luminosity. [W. J. Fischer, S. T. Megeath, E. Furlan, B. Ali, A.M. Stutz, ...,P. Manoj, C. Poteet, J. Booker et al.]

**Excitation Mechanism of O I Lines in Herbig Ae/Be Stars**

We have investigated the role of a few prominent excitation mechanisms viz. collisional excitation, recombination, continuum fluorescence, and Lyman beta fluorescence on the O I line spectra in Herbig Ae/Be stars. The aim is to understand which of them is the central mechanism that explains the observed O I line strengths. The study is based on an analysis of the observed optical spectra of 62 Herbig Ae/Be stars and near-infrared spectra of 17 Herbig Ae/Be stars. The strong correlation observed between the line fluxes of O I \( \lambda 8446 \) and O I \( \lambda 11287 \), as well as a high positive correlation between the line strengths of O I \( \lambda 8446 \) and Hz suggest that Lyman beta fluorescence is the dominant excitation mechanism for the formation of O I emission lines in Herbig Ae/Be stars. Furthermore, from an analysis of the emission line fluxes of O I \( \lambda 7774, 8446 \), and comparing the line ratios with those predicted by theoretical models, we assessed the contribution of collisional excitation in the formation of O I emission lines. [B. Mathew, P. Manoj, M. Narang, D. P. K. Banerjee, P. Nayak, S. Muneer, S. Vig, S. Pramod Kumar, K. T. Paul and G. Maheswar]

**Members**


Research Scholars

Visiting Fellows
Chandrachur Chakraborty (till August 2017), Sunil Chandra (till August 2017), Priyanka Chaturvedi (April 2017 – March 2018), Arjun Datta, Subhrangshu Ghosh (August 2017 – April 2018), Blesson Mathew (till June 2017), Rajibul Shaikh, Gargi Shaw (DST Women Scientist)

Junior / Senior Research Fellows
Chauhan J. (till February 2018), Rateesh Ajay, Warang Kasturi V.

Project Staff
Prashant P. Vyas

Administration
Magnes S. Johny, Shobha Shenoy

National and International Involvement

Sudip Bhattacharyya
1. Life member, Indian Science Congress Association
2. Member, Astronomical Society of India
3. Elected member, International Astronomical Union
4. Life member, The National Academy of Sciences, India
5. Life member, Indian Association for General Relativity and Gravitation
6. Associate, COSPAR
7. Payload Manager or PI, AstroSat Soft X-ray Telescope
8. Faculty-in-charge, AstroSat Soft X-ray Telescope Payload Operations Centre
9. Member-secretary, AstroSat Science Working Group (the apex science body of AstroSat)
10. Member, AstroSat Time Allocation Committee (ATAC)
11. Member, Consortium of the future X-ray space mission “enhanced X-ray Timing and Polariometry mission (eXTP)”
12. Member, four “enhanced X-ray Timing and Polariometry mission (eXTP)” Science Working Groups
13. Member, SKA international “Pulsar” science working group
14. Member, two “Square Kilometre Array (SKA)-India” Science Working Groups
15. Member, “Square Kilometre Array (SKA)-India” Executive Council
16. Member, Athena X-ray observatory science working group: “SWG 3.3: The End points of stellar evolution”
17. Member, TIFR team contributing to the building of the “Thirty Meter Telescope”
18. Member, Thirty Meter Telescope (TMT) International Science Development Team (ISDT): “Time domain science”
19. Participant, Scientific and Technological cooperation in X-ray Astronomy between The Netherlands Organisation for Scientific Research Board of Physical Sciences and the Tata Institute of Fundamental Research
20. Member, two GWIC 3G SCT Working Groups: NS EoS and NS Pops (gwic-3g-ns) and Compact Binaries (gwic-3g-binaries)

Shravan Hanange
Member, International Astronomical Union (since 2015)

D. K. Ojha
1. Member, Time Allocation Committees of IIA and ARIES telescopes (Currently serving as Chairperson of IIA-TAC)
2. Member, Scientific Advisory Committee (SAC) of ARIES, Nainital
3. Member, International Science Development Team (Formation of stars and planets), Thirty Meter
Telescope Project
4. Member, TIFR Balloon Facility Management Board
5. Member, NCRA Management Board
6. Member, National Committee for Astronomy-IAU, INSA, New Delhi
7. Member, Scientific Organizing Committee of Astronomical Society of India, 2016–19
8. Member, Project Management Board of India TMT Coordination Center (ITCC)

Many Puravankara
1. Lifetime member, Astronomical Society of India (ASI)
2. Member, International Astronomical Union (IAU)
3. Member, India-TMT Science Advisory Committee
4. Member, India-TMT Coordination Committee (ITCC)

Visits

Sudip Bhattacharyya
1. Invited Chair, ‘Hard X-ray Polarisation from Black Hole Sources’ meeting, Panchgani, March 29, 2018
2. Invited Chair, ‘AAPCOS-2018 conference’, SINP, Kolkata, 08 March, 2018
3. Invited Chair, ‘Multi-Wavelength Neutron Star Workshop’, BITS-Pilani, Hyderabad, 08 January, 2018
4. Participant, ‘SKAIC Brainstorming Meeting’ NCRA, Pune, December 09, 2017
5. Participant, ‘SKAIC Executive Council meeting’, NCRA, Pune, December 08, 2017
6. Participant, AstroSat Time Allocation Committee meeting to discuss 154 AstroSat proposals, IUCAA, Pune, 01 – 02 August, 2017
7. Invited Chair, RETCO-III 2017 Conference, IIST, Thiruvananthapuram, 07 June, 2017

A. Gopakumar
1. Albert-Einstein-Institut, Hannover, Germany Institute for Theoretical Physics (ITP), Goethe University of Frankfurt, Germany, 2 – 5 May, 2017
2. University of Regensburg, 8 – 9 May, 2017
3. Astrophysical Institute and University Observatory Friedrich Schiller University Jena, Germany, 10 – 12 May 2017
4. Department of Physics, University of Zurich, 15 – 29 May, 2017

Shravan Hanasoge
1. Center for Space Science, New York University, Abu Dhabi, April 16 – 20, 2018
2. International Conference in Solar Physics, Jaipur, February 15 – 18, 2018
3. Center for Space Science, New York University, Abu Dhabi, February 11 – 15, 2018
4. ICTS, Bangalore, January 19 – 24, 2018
5. Center for Space Science, New York University, Abu Dhabi, January 14 – 19, 2018
7. SCOR meeting on convection in the Sun, University of Heidelberg, Germany, October 16 – 19, 2017
8. Center for Space Science, New York University Abu Dhabi, October 20 – 26, 2017
10. Department of Earth Sciences, Cambridge University, UK, August 10 – 17, 2017
13. Department of Earth Sciences, Cambridge University, August 2017

D. K. Ojha
1. IUCAA, Pune, September 21 – 22, 2017, January 10 – 12, 2018 and January 22 – 24, 2018
2. University of Tokyo, Japan, October 17 – 20, 2017
3. National Astronomical Observatory, Japan, Mitaka, Tokyo, Japan, October 20 – 31, 2017
4. North-Eastern Hill University, Shillong, Nov. 3–5, 2017
5. Osmania University, Hyderabad, February 5 – 8, 2018
6. ARIES, Nainital from February 22 – 24, 2018
7. IISc, Bengaluru, March 2, 2018
8. PRL, Ahmedabad, March 5, 2018
9. Institute of Applied Physics, Russian Academy of Sciences, Nizhny Novgorod, Russia, March 30 – April 4, 2018

Many Puravankara
1. Infosys Campus, Mysore (to attend the TMT science forum), 5 – 12 November 2017
2. ‘Future Exploration of Star and Planet Formation with Subaru’ Workshop, Academia Sinica Institute for Astronomy and Astrophysics, Taipei, Taiwan, 6–12
Invited Talks

H. M. Antia
2. Numerical Techniques for Ordinary Differential Equations (3 lectures). School cum First Collaboration Meeting on Computational Nuclear Structure and Reactions, January 4–6, 2018
3. Stellar Convection: Turbulence from Angstrom to Light Years. ICTS, Bangalore, January 21, 2018

Sadip Bhattacharyya
1. GRS 1915+105. ‘Hard X-ray Polarisation from Black Hole Sources’ meeting, Panchgani, India, 30 March 2018
2. Do gravitational waves limit the spin rates of millisecond pulsars? AAPCOS-2018 Conference, SINP, Kolkata, 8 March 2018
3. What limits the spin rates of millisecond pulsars: disk-magnetosphere interaction or gravitational waves? Multi-Wavelength Neutron Star Workshop, BITS-Pilani, Hyderabad, 7 January, 2018
4. AstroSat SXT and LMXBs. ASSC Workshop, IUCAA, Pune, 13 November, 2017
5. Low-mass X-ray Binaries with TMT. TMT Forum, Mysore, 7–9 November, 2017
6. Transient accretion and the spin rates of millisecond pulsars. RETCO-III 2017 Conference, IIST, Thiruvananthapuram, 5 June, 2017

A. Gopakumar
1. Efforts to authenticate binary black hole central engine model for OJ287. ‘AstroSat View of the AGN Central Engines’, IUCAA, 18–21 Dec, 2017
2. GR centenary flare from OJ287 and its implications. Goethe University of Frankfurt, University of Regensburg, Friedrich Schiller University Jena and University of Zurich, May 2017
3. Au-some cosmic explosion: Dawn of multi-messenger gravitational wave Astronomy. TIFR, Mumbai, Calicut University, Cochin University, Sir P. T. Sarvajanik College of Science during October 2017 – March 2018

Shravan Hanasoge
1. IUCAA Colloquium, Pune, October 2017
2. Long-term datasets in solar physics. IAU symposium, Jaipur, February 2018

M. N. Vahia
Xth International Olympiad in Astronomy and Astrophysics, Indonesia

D. K. Ojha
1. Astronomy at TIFR. Third BRICS Workshop on Astronomy Infrastructure and Instrumentation, IUCAA, Pune, September 22, 2017
2. Prospects of star formation studies with near infrared instruments on 2–4 meter class Indian ground-based telescopes. AKARI2017 Conference: The Cosmic Wheel and the Legacy of the AKARI archive: from galaxies and stars to planets and life, University of Tokyo, Japan, October 17, 2017
4. Astronomy at TIFR. First Indo-Chilean Astronomical Dialogue Meeting, IUCAA, Pune, January 11, 2018
5. A Stellar Population Synthesis Model for the Study of Ultraviolet Star Counts of the Galaxy. International meeting on Galaxy Evolution and Dynamical Structures–I (GEDS 2018), IUCAA, Pune, Jan 24, 2018
6. TANSPEC overview and possible science cases. 36th Annual Meeting of the Astronomical Society of India’s Workshop on ‘Early science with the newly installed 3.6m Devasthal Optical Telescope’, Osmania University, Hyderabad, February 5, 2018
7. Research on Space Science using Balloon Platforms. ISRO-Structured Training Programme (Space Science Programme: ISRO & Global Scenario), PRI, Ahmedabad, March 5, 2018

Manoj Puravankara
Jets and Outflows in Young Stellar Objects. Workshop on Astrophysical Jets, Astronomical Society of India meeting, Hyderabad, 5 February 2018

M. N. Vahia
1. Series of lectures in Tripura, invited by the state Science and Technology Council, Tripura, January 4 - 13
2. Evolution of science. TCIS, Hyderabad

Nisha Yadav
1. Computational Studies of the Indus Script. STCS Seminar, School of Technology and Computer Science, TIFR, April 19, 2017
3. Structure of Indus Script. National Conference on Cross-disciplinary Applications of Complex Networks, Department of Mathematics, Shiv Nadar University, Uttar Pradesh, March 23, 2018

Conferences Organised by the Department

Pulsar Astronomy with uGMRT Boot-Camp and Multi-Wavelength Neutron Star Workshop
BITS-Pilani, Hyderabad Campus, January 3 – 8, 2018

First TIFR-BARC interaction meeting on Astrophysics, High Pressure & Synchrotron Radiation Physics
TIFR, Mumbai, January 13, 2018

DAA Annual Interaction Meeting (DAIM-2018)
TIFR, Mumbai, January 15 – 16, 2018

Turbulence from Angstroms to Light Years
ICTS, Bangalore, January 20 – 25, 2018

Hard X-ray Polarisation from Black Hole Sources
Panchgani, March 29 – 30, 2018

Non-DAE Research Projects

Shravan Hanasoge
1. Shell seismology research project, December 2017 – present
2. Shell Consultancy Project, June 2015 – present
3. Max-Planck Partner Group Program
4. Indo-US Science and Technology Forum Conference Grant
5. Early Career Award (awarded by SERB)
6. Ramanujan Fellowship (awarded by SERB)

D. K. Ojha
Multi-wavelength studies of Galactic star-forming regions. DST-RFBR Indo-Russian Joint Research Programme (Start date: May 2017; Duration: 24 months)
Parasite Biology

**Plasmodium falciparum proteins interact with red blood cells**

PfP0 and PfP2, ribosomal proteins, as well as enolase (Pfeno) protein of *P. falciparum*, perform novel functions. The post-translational modifications of these proteins have been investigated. While phosphorylation of serine residue seems to be occurring, differential phospho-tyrosination appears to be happening for PfP2 in the parasite versus that on the infected RBC membrane. Immuno-precipitation data indicates complex formations between PfP2, Pfeno of *Plasmodium*, and Band 3 protein present on RBC membrane. [Crismita Dmello, Rina Verma, Vrushali Pathak, S. Sharma with G. K. Jarori]

**Circumsporozoite protein may confer surface flexibility in cells**

The circumsporozoite protein (CSP) is the major surface protein of the infective sporozoite stage of the malaria parasite and is a major candidate for a malaria vaccine. We have recently hypothesized a mechanically pliable structure for *P. falciparum* CSP using single molecule atomic force spectroscopy. We have reported results of force microscopy and motility assays on cellular slime-mold *Dictyostelium discoideum* cells expressing CSP on its surface. Our findings suggest that the overall low mechanical resistance of CSP may provide the sporozoite surface with flexibility and pliability, possibly providing a lubricating capacity required for its long and penetrating journey. Certain crucial control constructs using deleted CSP regions and a structurally rigid muscle protein (I-27) are currently being studied to confirm this hypothesis regarding provision of flexible surface. [Crismita Dmello, Vrushali Pathak, Aditya Patra and S. Sharma in collaboration with ASR Koti, DCS, and Arun Kumar Kota, UoH]

**Age and sex-dependent long term effects of mild malaria in murine models**

A single episode of mild malaria in an adult mouse causes specific behavioural changes. Using a self-resolving murine mild malaria model, we show that a single *Plasmodium chabaudi adami* infection in adult mice causes effects on neurogenesis in the brain. A single episode of mild malarial infection was seen to exert sexually dimorphic immune and neuronal effects during the acute phase of the infection in adult mice, with no long-term neurological effects. When infection was introduced in juvenile animals, no sexual dimorphism was observed. However, in the neuro-immunoconsequences of malaria, both short- and long-term neuronal consequences of infection were observed, which would indicate further predisposition to stress, mood-related disorders, or neurodegenerative diseases. Given that 90% of the malaria patients world-wide are children, these observations indicate severe implications for the future of these children. [Suhasini Yellai, S. Pathak and S. Sharma; in collaboration with V. Vaidya]

**Genomes and Physiology**

Continuing our efforts from the previous year where we described the identification and characterization of a novel isoform of Sirt1 that is expressed in a tissue restricted manner, we have now demonstrated that the short isoform lacks a protein domain encoded by exon-2 in SIRT1 gene. Work done during the previous year had indicated that the exon-2 domain in full length SIRT1 could be involved in encoding specificity of interactions. In this regard we have now found that exon-2 od SIRT1 is both necessary and sufficient to bind to PGC1a which a master regulator of transcription by coactivating several transcription factors. Using both immuno precipitations and GST-pulldown assays we have shown that exon-2 of SIRT1 plays a deterministic role in binding to PGC1a. We have also unravelled that presence or absence of exon-2 alters the binding efficiency of SIRT1 with PPARα, FOXO1, FOXO3 and p53. We have also worked out
the physiological relevance of these interactions. This study will significantly advance our understanding of the molecular properties of Sirt1 given its crucial role in aging and age-related diseases (Diabetes, Obesity and Cancer). Moreover, these findings will enhance our understanding of this longevity factor.

We published this aspect of the project in a high impact journal, which also received some media attention due to the obvious implications on biomedical applications. Following this aspect of how domains in key regulatory proteins encode specificity, we have found that a novel modification could be involved in determining substrate switching in SIRT1 and also its stability. A tight regulation of cell division cycles is important to sustain life and any aberration leads to either cell death or over-proliferation like in cancers. Briefly, our efforts to unravel novel deacetylation targets of SIRT1 have shown that CDK1 is post-translationally modified by acetylation. CDK1 is an essential protein without which cell division does not occur. Pioneering work by Paul Nurse, Tim Hunt and others led to the identification of CDK1 and control of its activity by phosphorylation-dephosphorylation cycles. Providing a very novel twist to CDK1 dependent control of mitosis, we have found CKD1 is acetylated at critical lysine residue in its active site (K-33). Using both proteomics and biochemical experiments we have established this modification. Mutating this lysine residue to glutamine that mimics acetylation abrogates cell division. Our results demonstrate that SIRT1 interacts with CDK1, possibly to deacetylate it. As mentioned earlier we are in the final phase of this project and this is likely to have a defining impact on how cell cycle is regulated. It will add a new dimension to the information that is in the textbooks.

Neural and Developmental Biology

Control of the neuron-glia cell fate switch in the developing hippocampus

We discovered that Lhx2 interacts with Dmrt5, which mediate its role in suppressing astrogliogenesis and promoting neurogenesis in the developing hippocampus. [Muralidharan et al., 2017b, Journal of Neuroscience]

Patterning of the early telencephalon

We discovered that transcription factor Foxg1 regulates Lhx2 expression, and suppresses the signaling center called the cortical hem via Lhx2. Furthermore, we discovered that Pax6 is required to suppress hem fate in the lateral telencephalon, together with Lhx2. [Godbole et al., 2018, Development; Godbole et al., 2017, Neural Development]

Pax6 can substitute for Lhx2 function in suppressing gliogenesis in the developing hippocampus

We discovered that Pax6 overexpression can substitute for loss of Lhx2 and also can override the progliogenic effects of Nfia, similar to the functions reported for Lhx2. [Kinare et al., 2018, Journal of Biosciences]

Neurobiology of stress and depression

The major research focus of our team is to examine the epigenetic, molecular, cellular and cytoarchitectural changes in neurocircuits that regulate mood-related behavior in response to (a) early adversity and (b) pharmacological drugs that treat anxiety and depression. In the past year we have identified the role of Gq-mediated signaling and neural activation in the medial prefrontal cortex (mPFC) in regulation of anxiety-like behavior. We have also shown that acute stress evokes starkly differing, sexually dimorphic neural activation patterns in male and female rats within limbic brain regions. Further, our work has identified a role for the 5-HT2A receptor in early stress and the metabolic consequences of adult-onset chronic stress. Our results add to our understanding of the molecular and cellular mechanisms that underlie the pathophysiology of mood disorders. [Sashaina Fanibunda, Dwight Figueiredo, Pratik Chaudhari, Antara Banerjee, Ankit Sood, Shitapriya Pati Toshali banerjee, Praachi Tiwari, Sneha Shah, Utkarsha Ghai, Darshana Kapri, Sonali Salvi, Sukrita Deb, Ashmita Chatterjee]

Early development of zebrafish embryos

Our research group uses the vertebrate model organism, zebrafish, to understand the cellular and molecular processes that govern the transformation of a one cell embryo into a three dimensional organism. During the convergent extension phase of gastrulation, cells converge towards the dorsal midline and extend...
along the antero-posterior axis. Evolutionarily conserved molecular blueprints such as the Planar Cell Polarity (PCP) pathway is required to establish a three dimensional embryonic body plan. Though we know in considerable detail molecular interactions that dictate convergent extension, the fundamental contribution of cell size to this process remains largely unexplored. We sought to address this in haploid and tetraploid zebrafish as these embryos are indistinguishable from diploids, particularly during gastrulation. Phenotypic abnormalities become evident later, resulting in eventual death of non-diploids. Comparative transcriptomics of haploids, tetraploids and diploids at 3 hours post fertilization (hpf), revealed that the transcriptomes of haploids and tetraploids were largely unaltered, with only a few genes being misregulated in response to alteration in ploidy. However during gastrulation, the cell sizes in haploids are smaller and those in tetraploids are larger in comparison to stage matched diploid embryos. This is expected because cell size is known to scale with ploidy. Surprisingly, analysis of the spatial domains of genes in haploids and tetraploids revealed classical convergent extension defects that mimicked those that manifest upon defective PCP signaling. This is significant in light of the fact that the expression levels of genes required for antero-posterior, dorso-ventral and PCP signaling pathways are not misregulated in non-diploids. Our work shows that in non-diploids, the cell biological landscape is fundamentally different, which is sufficient to trigger aberrant convergent extension despite normal expression of conserved genes required for this process. We propose that primarily cell sizes dictate coordinated migration of cells during convergent extension, which conserved molecular signals reinforce to ensure normal embryonic patterning.

**Adaptive Homeostasis in the Olfactory System**

Intrinsic excitability of a neuron is a key determinant of how effectively a neural circuit performs computation; instability in a neural circuit due to excitation-inhibition imbalance can lead to pathological conditions like epilepsy and Alzheimer’s disease. Homeostatic mechanisms play a key role in maintaining circuit stability. However a neural circuit also needs to accommodate for plastic changes like synaptic potentiation/depression so that the circuit can adapt to organismal needs. We are using Drosophila to understand how a ‘fluid’ homeostatic state is created and maintained in a neural circuit. Using transcriptional analysis, functional imaging, high-resolution behaviour and computational modelling, we have demonstrated that intrinsic excitability of neurons are dynamically regulated in different sensory milieu via transcription to homeostatically maintain the dynamic range for stimulus detection and discrimination. We have also identified candidate genes that regulate this homeostatic process and are currently working towards validating these targets. [Arpan Parichha, Dipesh Chowthe and Asmita Sarkar]

**Neurobiology of Path Integration in Drosophila**

Path integration is a process by which organisms estimate their location relative to a landmark in the absence of external cues. Behavioural studies have revealed that ants can estimate distances from their nest sites by using a method akin to footstep counting; however, the neural mechanism of this process remains to be identified. Using a novel paradigm developed in our lab, we can now demonstrate that, like ants and bees, flies are also capable of performing path integration. We have also identified candidate neurons that are responsible for providing the footstep information to the central brain and currently performing a genetic screen to identify the synaptic partners of these sensory affrents. [Anzal K S]

**A Neuronal Substrate for Evidence-accumulation during Decision-making**

During perceptual decision-making, sensory evidence is accumulated by integrator neurons to generate decision-bias that leads a choice. If the evidence in favour of one choice is compelling, the commitment to that choice builds quickly and the decision times are short. However, the decision develops slowly and the decision times are prolonged when the evidence is conflicting. Although this evidence-integration process plays a central role in perceptual decision-making in humans, non-human primates, rodents and insects, the biophysical basis of the evidence-accumulation remains unclear, in any system. Using olfactory decision-making paradigm in Drosophila, we have identified a biophysical substrate of evidence-accumulation; our data shows that membrane-voltage of in the ab core neurons fits the necessary criterions for accumulated evidence and is a good predictors for reaction time and decision-accuracy during olfactory decision-making. We are currently developing a virtual-reality arena to investigate the activity patterns of these neurons during decision-making. [Sashi kiran Mahapatra, Anzal K S]
State-dependent Modulation of sensory coding

State dependent gating of sensory information is a ubiquitous phenomenon across model systems. Foraging animals, including insects, modulate their foraging behaviour in accordance with their energy demands. We are currently investigating how hunger and satiety influences foraging strategies used by Drosophila to locate food-source. Our data shows that feeding-dependent modulation of foraging is a multi-sensory phenomenon and metabolic states in Drosophila modulate olfactory, gustatory and potentially visual coding. We are currently investigating the cellular basis of these modulations and how they influence the foraging behaviour. [Abhrojyoti Chakrabarty, Rahul Kushwaha]


An emerging theme in modern neuroscience is to couple molecular level observations, e.g. mRNA and protein level measurements, with high-resolution anatomical analysis in intact tissues to augment the substance and the context of molecular level observations. However, performing mRNA and protein level analysis in an intact tissue is often technically problematic, as the protocols often require disassembling the tissue. Thus a major focus in neuroscience is to develop techniques that allow simultaneous RNA fluorescent in-situ hybridization and protein immunofluorescence analysis of intact tissues. We have recently developed a protocol that allows us to perform protein immunofluorescence analysis under RNA fluorescent in-situ hybridization conditions in intact brain tissues and we are currently optimizing this protocol for robust RNA preservation and access in intact, transparent brain volumes. The long-term goal of this project is to create a neurotransmitter usage atlas of the Drosophila brain. [Abhrojyoti Chakrabarty]

Motor Biology

A mechanism for controlling Lipoprotein secretion from the Liver across Feeding-Fasting cycles

The liver secretes lipids in a controlled manner despite vast changes in its internal lipid content. This buffering function of the liver is essential for lipid/energy homeostasis, but its molecular and cellular mechanism is unknown. We show that the motor protein kinesin transports triglyceride-rich lipid droplets (LDs) to the endoplasmic reticulum (ER) in liver cells. This supplies triglycerides for packaging into lipoprotein particles (VLDL) that are subsequently secreted from the liver. However, when fasting induces massive lipid accumulation in liver, kinesin is removed from LDs to inhibit triglyceride supply and homeostatically temper lipid secretion from liver. Most interestingly, this entire pathway is controlled by insulin, and can therefore respond to fed/fasted states of the animal. Reducing kinesin also blocks propagation of hepatitis-C virus inside liver cells, possibly because viral proteins now cannot transfer from the ER to LDs. [Priyanka Rai, Mukesh Kumar, Hemangi Bhonsle, Jagjeet Singh, Srikant Ojha, Roop Mallik]

Tossing Coins inside Cells

The unit generator of force that drives almost all biological movement is a nanoscale molecule called a motor protein. We have used optical trapping to measure the force generated by these motors on micron-sized particles inside cells. Our analysis shows that the choice between antagonistic motors can be described by the tossing of a coin. These experimental results and their analysis suggest that the organization of different compartments inside a cell can be understood by simple physical and geometrical arguments. [Paulomi Sanghavi, Ashwin D’Souza, Ashim Rai, Arpan Rai, Ranjith Padinhatheeri and Roop Mallik]

Axonal Transport of soluble and membrane-associated proteins in Drosophila

Axonal transport is essential for neuronal growth and homeostasis of the nervous system. Our long term interest is to correlate the transport of specific axonal material and the nervous system function. We had earlier established that heterotrimeric kinesin-2 is involved in the anterograde transport of soluble choline acetyltransferase (ChAT) and membrane bound acetylcholinesterase (AChE) in Drosophila. We have now established that the same motor is needed to transport Rab4-associated vesicles in the same axon. The results suggest an antagonistic relationship between the ChAT and Rab4 vesicle transport that is correlated to the synapse assembly in Drosophila ganglia.
Cholinergic activity-dependent feedback appears to maintain the anterograde movements of these two cargoes. We are now investigating the quantitative correlation between the flux and synapse reorganization during the developmental restructuring of larval ganglion. These results may have long-term implications in understanding the cellular and molecular basis of nervous system plasticity. [S. Dey, A. Kulkarni, D. Rai, P. Patil]

Molecular Cell Biology of Spermatogenesis in Drosophila

Sperm development and differentiation occurs within somatic cell enclosure. Once matured, the spermatids are released into the seminal vesicle for utilization. It is a carefully regulated quality control filter, which maintains male fecundity. We found that signalling based on Mitogen-Activated Protein Kinase, ERK, in the neighbouring somatic cyst cells synchronizes the germ cell divisions within a cyst through a novel mechanism. Also, an episodic increase in the somatic ERK activation interspersed between germ cell divisions appeared to determine the rate of transit amplification divisions and differentiation of the stem cell progeny. Anomalous alterations of the ERK activation pulses altered the rate of the germ cell divisions in a stage-specific manner. We are currently investigating the downstream components of the ERK signalling to unravel the detailed molecular mechanism. These results may have implications in understanding the role of microenvironment in regulating the transit amplification of stem cell progeny in other systems. [S. Gupta, S. Chatterjee, C. Joshi, P. Gadre]

Cryo-Electron Microscopy Facility

This facility was established in 2007 with a Zeiss Libra 120 EFTEM and two ultracut sectioning machines. It is now running at optimum, and several members from the Institute and from outside have availed it for their research. [S. Shirolikar, L. Borde]

Cell Biology

The epidermis, an outermost tissue of the vertebrate skin, is a stratified epithelium. It develops from a non-neuralised ectoderm, which gives rise to initial bilayered epidermis that eventually stratifies. In adults, it acts as a barrier to retain body fluids and to prevent entry of pathogens whereas during embryogenesis it maintains the milieu interior that allows normal animal development. Therefore, maintenance of integrity and architecture of the epidermis is essential for normal development and survival of the organism. The establishment and maintenance of epithelial architecture depends on cellular features such as cell morphology, cell polarity and cell adhesion. We combine genetic, chemical and mechanical perturbations with imaging to investigate mechanisms that regulate these cellular features in the developing epidermis, using zebrafish as a model.

In the recent past, we have shown that the maintenance of plasma membrane homeostasis, especially by Myosin Vb, is essential for regulation of cell size and tissue homeostasis. Our recent data indicate that the Rab10 binding isoform of Myosin Vb is essential for membrane biogenesis. In the absence of this isoform, the surface area, volume as well as tubulation of Golgi increases. Besides, large vesicles are seen attached to the trans-Golgi surface indicating that the Myosin Vb function is essential for the scission of these vesicles. Furthermore, the growth of peridermal cells, in the absence of cell proliferation, requires function of this Rab10 binding isoform. Our data indicate that the Myosin Vb mediated membrane transport from Golgi is required for cell size growth in the absence of cell proliferation. [Kirti Gupta, Sudipta Mukherjee]

Actin based epithelial projections are important for secretion and absorption. The outermost layer of the zebrafish embryonic and larval epidermis exhibits microridges, which are thought to be essential for mucous retention. The microridges are present in several non-keratinised epithelial cells in vertebrates, including mammals. Our previous analyses suggest that aPKC controls the microridge elongation by maintaining low levels of Lgl and phospho-Myosin II at the apical domain (Raman et al 2016). We are currently investigating whether the differential rate of actin polymerization/depolymerisation and Myosin II activity controls these patterns. Besides, we are analysing the importance of membrane composition and actin binding proteins in microridge formation and maintenance. [Clyde Pinto, Ameya Khandekar, Bhavna Rajasekaran]

How tissue polarity is established in stratified epithelia...
has remained largely unclear. We have been analyzing functions of cell polarity regulators aPKC, Lgl and Crumbs in the developing zebrafish epidermis. Our analyses show that aPKC function is important for robust polarization of E-cadherin localization in the periderm. In addition, both aPKC and Lgl control the levels of E-Cadherin in periderm as well as in the basal epidermis. Importantly, our analysis indicate that E-cadherin controls the adhesion status as well as polarity in a layer-non-autonomous manner and may be a crucial component involved in transmitting polarity cues across the cell layers. [Prateek Arora]

Using a new paradigm to induce hydrostatic stress on the epidermis, we have been able to show that E-cadherin function is essential to endure stress. In collaboration with Dr. Koti’s group at the department of chemical sciences, we have used AFM to measure the tension in the native epidermis as well as upon induction of hydrostatic stress. We are teasing apart the relative contribution of cell size and cell adhesion in stress endurance. Our recent analyses indicate that cell number increase upon induction of stress has no functional significance but cell adhesion plays more important role in stress sustenance. [Geetika Chouhan]

Role of Notch signaling in the control of cell behaviour

Cell delamination is diversely deployed for fate specification, force generation and cell number homeostasis. In the amnioserosa during Drosophila dorsal closure, cell delamination is a rare and stochastic event that contributes forces for its contraction. What cues trigger cell delamination has been unclear. Our work has found that reduction in Notch receptor levels on the membrane by Notch internalization and degradation trigger cell delamination. This generates differences in Notch receptor levels between a cell and its neighbours and is sufficient to direct differential adhesion and cytoskeletal organization between them. Our work uncovers the interplay between signaling and cell behaviour and delineates a mechanism by which emergent changes in the output of signaling pathways can contribute to heterogeneities in cell behaviour within a tissue. [Chugh, Soans, Pramanik and Narasimha]

Interplay between the actomyosin and microtubule cytoskeleton in the control of cell behavior

Our previous work had demonstrated that differences in actomyosin organization underlie differences in cell behaviour observed in the amnioserosa. We have identified a role for microtubule dynamics in directing myosin movement and the molecular mechanism that underlies this dependency, the spatial regulation of Rho signaling. Collectively, our work has identified a mechanism for self-organised cell behaviour and cytoskeletal organization during tissue dynamics. [Saravanan, Guru and Narasimha]

Fusion fidelity and epithelial continuity

Epithelial fusion mediates dorsal closure in Drosophila, neural tube closure in vertebrates and wound healing. Our work on dorsal closure has identified physical, cellular and molecular mechanisms that contribute to fusion fidelity and epithelial continuity. Specifically, it has uncovered both genetically hardwired and emergent mechanisms (cell shape changes and cellular rearrangements) that contribute to fidelity in epithelial fusion. Our work also identified the mode and molecular mechanisms of interface remodeling at fusion and has delineated the interplay between adhesion, polarity and cytoskeletal complexes in establishing strong epithelial barriers [Das Gupta and Narasimha]

Forces contributing to organ positioning

Germ band retraction is a morphogenetic process that positions the hindgut, the amnioserosa and the posterior embryonic segments during Drosophila embryogenesis. Our work has uncovered the molecular and cellular origins of forces that drive it. Our analysis reveals that regulated sliding contributes to tissue unfolding and provided a mechanism by which groups of cells within the same sheet can be moved to different locations in the embryo. [Nandi and Narasimha]

Native structure of fission yeast actomyosin ring during constriction

Accumulation of an equatorial zone of unbranched actin filaments at the division plane was discovered more than four decades ago, yet how the actin filaments organise to generate contractile force and how constrictive force from the ring is transmitted to the membrane remain poorly understood. We visualize the rings more clearly by imaging intact cells in their native state using electron cryotomography (ECT). Bundles of straight, overlapping actin filaments running parallel to one another were seen “saddling” the septum, but no direct contact between filaments and the membrane were observed, challenging theories that actin filaments
are connected individually to the membrane at their barbed-end or at large protein nodes embedded in the membrane. Correlative light and electron microscopy further shows that myosin does not form thick oligomeric complexes in the rings.

Reconstitution of cytokinesis using model membrane systems that mimic the topology of the yeast cell

Three decades of research using classical and reverse genetics has identified close to 130 proteins involved in cytokinesis, most of which are conserved from yeast to mammals. While we know the identity and number of proteins that recruit and later constitute the contractile ring, the molecular mechanisms underlying ring assembly, its contraction and the transmission of forces thus generated to the membrane remain elusive. The complex environment of the cell containing myriad proteins presents a hurdle in appreciating the broad design principles by which proteins involved in cytokinesis manage membrane remodeling leading to cell division.

We are using a reconstitution approach, using novel model membrane systems that mimic the spherical geometry of a dividing cell. Taking cues from a large body of cell biological work focused on analyzing cytokinesis, we have developed a system of unilamellar vesicles by encapsulating specific proteins involved in cytokinesis in the lumen of these vesicles. Using this approach we aim to (a) identify the minimal repertoire of proteins sufficient to form a contractile actomyosin ring, (b) map the spatiotemporal dynamics of ring assembly, and (c) gain mechanistic insights into the pathway of membrane ingestion possibly leading to fission.

We aim to build on these observation to eventually build a minimal contraction competent actomyosin ring in vitro. Our specific aims would be to:

1. Monitor dynamics of actin-ring assemblies formed in the GUVs
2. Determine the ultrastructure of these assemblies, filament length, direction, and polarity
3. Increase complexity of the system by sequential addition of components that assist actin organization and test their effect on the dynamics of ring formation.
4. Tether the ring to the membrane using proteins with membrane binding domains like profilin and Cdc15 which have affinity for negatively charged lipids and have been shown to localize to the division site in cellular studies.
(A) Lysate from S. pombe cells expressing LifeActGFP. (B) Cytosolic actin polymerizes to form dense bundles and asters on a planar surface. Scale bar 2 μm. (C–D) Encapsulation inside GUV and line profile of encapsulated GUVs. (E) Vesicle distribution, (F) Encapsulation efficiency. (G) Curvature sensitivity of encapsulation. (H) Ring-like assemblies of LifeActGFP formed in cytosol. Scale bar for C, H 5 μm.

Members

Champakali Ayyub, Hema Bagul, Ch Balaji, Boby K.V., Lalit Borde, Kalidas Kohale, Jyotish Parmar, Shubha Shanbhag, Seema Shirolikar, Shital Suryavanshi

Research Scholars
Abhrojyoti Chakroborty, Dipesh Chowthe, Shaunak Deota, Subhash L Khatri, Mukesh Kumar, Babukrishna Maniyanath, Triveni Menon, Arpan Parichha, Divya Pathak, Pankaj Rathaur, Anushree Ray, Kritika Sadh, Namrata Shukla, Jagjeet Singh

Visiting Fellows
Hemangi Bhonsle, Tandrika Chattopadhayay, Rahul Chaudhuri, Srishti Dar, Crismita Dmello, Vrushali Pathak, Paulomi Sanghavi, Eisha Shaw, Manasi Talwadekar, Rina Verma

Junior / Senior Research Fellows
K S Anzal, Sashi Kiran Mahapatra, Akshina Mehta

Msc Students

Administration
Veera Unhavane
National and International Involvement

Shamik Dasgupta
Review Editor, Frontiers in Neural Circuits, Frontiers, EPFL Innovation Park, Building I, CH – 1015 Lausanne, Switzerland

Ullas Kolthur
1. Member, American Society for Microbiology, 2011–present
2. Member, Society of Biological Chemists, India, 2012–present
3. Member, Department of Biotechnology (DBT) Task Force on Cancer, 2014–2017
4. Member, Department of Biotechnology (DBT) Task Force on Genome Editing Technologies, 2017–current

Roop Mallik
1. Member, Editorial Board, Nature Scientific reports
2. Member, American Society of Cell Biology
3. Member, Biophysical Society
4. Member, Guha Research Conferences
5. Member, DBT Modern Biology Task Force
6. Member, Expert Committee for Selection of Ramalingaswami Re-entry Fellowship
7. Member, National Centre for Cell Sciences (NCCS) Research Advisory Panel – Scientific Advisory Committee (RAP-SAC)

Mitilesh Mishra
1. Member, American Society for Cell Biology, 2016–present
2. Member, Society of Biological Chemists, India, 2017–present

Sreelaja Nair
1. Member, Indian Society of Developmental Biologists
2. Member, Society of Biological Chemists
3. Member, Indian Society of Cell Biology

Maithreyi Narasimha
1. Member, DBT Task force on Basic research in Modern Biology (till May 2017)
2. Co-opted Member, Program Advisory Committee, DST-SERB for Microbiology, Biochemistry, Molecular Biology and Biophysics
3. Member, Scientific Advisory Committee, International Congress of Cell Biology, Hyderabad, India, January/February 2018
4. Reviewer: eLife, Nature Cell Biology, PLOS Genetics, PNAS, Development

Krishanu Ray
1. Fellow and Life Member, Electron Microscope Society of India (EMSI), India
2. President (2014–2016) and Life Member, Indian Society for Developmental Biologists (InSDB), India
3. Life Member, Indian Society of Cell Biology (ISCB), India
4. Member, Guha Research Conference (GRC), India
5. Member, Research Area Panels-Scientific Advisory Committee (RAP-SAC), Centre for DNA Finger Printing and Diagnostics (CDFD), Hyderabad
6. Elected, founding member and Chair of the Indian Drosophila Board and Society (to be registered) in December 2017

Shebhaba Sharma
1. Fellow, Indian National Science Academy, New Delhi, (Nominated as Council member)
2. Fellow, Indian Academy of Sciences, Bangalore
3. Advisory Member, Malaria Foundation, New York, USA
4. Member, Editorial board of Journal of Vector Bourne Diseases, Delhi
5. Member, Scientific Advisory Committee of National Institute of Malaria Research, Delhi
6. Member, Scientific Advisory Committee of Institute of Life Sciences, Bhubaneshwar
7. Member, Review Committee Wellcome Trust-DBT India Alliance Early Career-Fellowship
8. Member, SERB Empowered Expert Committee, DST
9. Member, Executive committee, aur University, Sagar
10. Member, Board of Governors of NIT Rourkela

Shubha Tole
1. Member, Board of Reviewing Editors, Science, 2014–present
2. Member, Ethics Committee, Soc. for Neuroscience, 2014–present
4. Member, F1000, 2012–present
5. Member, F1000 Research Editorial Board, 2012–present
6. Member, Asia Pacific Regional Committee (APRC) of the IBRO (International Brain Research Organization), 2011–present
7. Member, International Affairs Committee, American Society for Cell Biology, 2009–present
8. Member, Society for Neuroscience (SFN), USA
9. Member, Indian Academy of Neuroscience (IAN)
10. Member, Indian Society for Developmental Biology (InSDB)

Vidita Vaidya
1. Member, Editorial Board, Neuropharmacology, 2016–Present
2. Member, Current Science 2016–Present
3. Associate Editor, Neuronal Signaling, 2016–Present
4. Member, Editorial Board, Progress in
Neuropsychopharmacology and Biological Psychiatry, 2012 – Present,
6. Member, Council of Scientists, Human Frontier Science Program (HFSP), 2018 – Present
7. Member, Program Advisory Committee, Regional Centre for Biotechnology, Faridabad, 2017 – Present
8. Member, Grants funding committee, Foundation for Medical Research, Mumbai, 2017 – Present

Visits

Shamik Dasgupta
Israel-India Neuroscience meeting, Eilat, Israel

Sreelaja Nair
1. Maternal reign on vertebrate embryogenesis: good, bad or ugly? National Center for Biological Sciences, Bangalore, India, August 2, 2017
2. Tardiness during embryogenesis: does the cause really matter? Center for Cellular and Molecular Biology, Hyderabad, India, May 17, 2017

Krishna Ray
1. Delivered departmental seminar, IISER-Kolkata, June 14, 2017
4. Attended, Annual Scientific Advisory Committee meeting of CDFD, CDFD Hyderabad, 29–30 Aug, 2017
6. Delivered two seminars and interacted with the faculty, on MRDG, IISe, Bengaluru, Oct 27 and Nov 3, 2017
7. Organized and attended, Biennial Indian Drosophila Research Conference (InDRC 2017), IISER-Bhopal, December 6–9, 2017

Shobhona Sharma
1. Structure and role of Circumsporozoite protein of Plasmodium falciparum sporozoite in cellular flexibility and motility; Use of D. discoideum as a model. Seminar at Stanford University, USA, May 21, 2017
2. Targeting ribosomal protein to impair cell division and growth of the malaria parasite Plasmodium falciparum. 5th international Congress on Bacteriology and Infectious Diseases, Chicago, USA, May 25–26, 2017

Mabendra Sonawane
1. Maintaining epidermal architecture in zebrafish: Control by regulators of cell polarity and Intracellular transport. Seminar at Max-Planck Institute for Developmental Biology, Tuebingen, Germany, 10–11 July 2017
2. Max-Planck Institute of Molecular Cell Biology and Genetics, Dresden, Germany, 11–22 October 2017 (to perform experiments on a collaborative project with Prof. Knust)

Shubha Tole
1. IMSc, Chennai, Feb 12, 2018
2. ICTS, Bangalore Jan 29, 2018
3. Center for NeuroSciences (CNS), IISc, Bangalore, Dec. 8, 2017
4. ‘Rendevouz’, CEBS, Mumbai Oct 5, 2017
5. International Society for Developmental Neuroscience (ISDN)-2018, Nara, Japan, May 22–25, 2018

Invited Talks

Roop Mallik
1. Physics on a Phagosome. Wellcome Trust meeting on Cell and Developmental Biology, Warwick, UK
2. Lipid Motor Interactions. Dept. of Mechanocellular Cell Biology, Warwick University (UK), 14 March 2018
3. Physics on a Phagosome. Young Investigators Meeting,
Trivandrum, 8 March 2018
4. Tiny Machines, Big Tasks. Delhi University South Campus, 21 Feb 2018
5. A Fat Story. Institute for Genomics and Integrative Biology, N. Delhi, 20 Feb 2018
6. Lipid-Motor interactions in Intracellular Transport. Rajiv Gandhi Centre for Biotechnology, Faridabad, Feb 19, 2018
7. Single Molecule Techniques. Advances in Science Engineering and Technology (ASET) Colloquium, TIFR-Mumbai, Feb 16, 2018
8. My life as a Scientist. Public Outreach Program for ICCB meeting, Kendriya Vidyalaya, Hyderabad. January 29, 2018
10. Tiny Machines, Big Tasks. Chemistry Department, St. Xaviers College Mumbai, January 2018
12. Tossing Coins on Vesicles. Natural and Artificial Molecular Machines meeting. IIT Mumbai, Dec 18, 2017
13. Proteins as Machines. Public Interaction Seminar, N. B. Mehta (Rural) Science College, Bordi, Dahanu, 2 December 2017
14. Nanoscale Machines. Saturday Series Lecture, Savitribai Phule University Pune, 28 October 2017,
15. Lipid-Motor interactions in Intracellular Transport. Institute of Biomembranes, Utrecht University, 21 July 2017
16. A Mechanism for Controlled Triglyceride Secretion from the Liver. Indian-Birmingham University Interaction Meeting, Birmingham (UK), 20 July 2017
17. Reactivation delay of Dynein as a Mechanism to control Intracellular Transport. EMBO | EMBL SYMPOSIUM: Mechanical Forces in Biology, Heidelberg, Germany, 12–15 July 2017
18. Teamwork in Molecular Motors: A Cell Biology Perspective. 28th Mid-Year Meeting of the Indian Academy of Sciences, Indian Institute of Science Bangalore, 1 July 2017
19. A Fat story. Learn from the Masters CDFD Lecture Series, Centre for DNA Fingerprinting and Diagnostics, Hyderabad, 17 May, 2017

Sreelaja Nair
1. Potentially conserved roles for comesdermin transcription factors in the vertebrate central nervous system. II Indian Zebrafish Investigators Meeting (IZIM), Alibaug, November 2–5, 2017

Maithreyi Narasimha
Exploring the origins of heterogeneity and collectivity in cell behavior during morphogenesis: lessons from a Drosophila epithelium. Dynamics of Complex Systems: Workshop on Physical and Systems Biology, ICTS, Bangalore, 12–25 June 2017

Krishnan Ray
1. Axonal Transport and Synapse Assembly: lessons from some recent experiments. InSDB 2017, IISER-Pune, June 24 – 27, 2017

Mahendra Sonawane
1. Intracellular transport and homeostasis: Implications in epidermal diseases. Annual meeting of European Society for Dermatological Research, Salzburg, Austria, 27–29 September 2017
2. Establishment and maintenance of epidermal architecture: genes and mechanisms. Symposium on ‘Advances in cell and developmental genetics, pattern formation and evolution’ organized by Prof. Christiane Nuesslein-Volhard, Ringberg Castle, Munich, 23–27 October 2017
Conference Organized by the Department

International meeting on Epigenetics, Male Germ Cell Maturation and Early Development
TIFR, Mumbai, February 14–18, 2017 (Organiser: Ullas Kolthur)

Mahabaleshwar Seminars on Molecular Biology on Current Trends in Intracellular Transport and Molecular Motors
IIT-B, Powai, December 21–23, 2017 (Organiser: Krishanu Ray)

Non-DAE Research Projects

Shamik Dasgupta
Genetic dissection of the neural circuits of decisions and actions. Human Frontier Science Program Career Development Award, Human Frontier Science Program (300,000 USD for 3 years)

Roop Mallik
Wellcome Trust-DBT Senior Research Fellowship, 2013 – 2018

Paulomi Sanghavi
Wellcome Trust-DBT India alliance Intermediate Fellowship, 2016 – 2021

Ullas Kolthur Seetharam
Investigating the role of mammalian Sirt4 in the regulation of mitochondrial functions and retrograde signaling to the nucleus. DST Swarnajayanti Fellowship, 2014 – 2019

Shobhona Sharma
International associated laboratory in the area of systems immunology and genetics infectious diseases. DBT-SIGID Grant, 2014-2018

Mahendra Sonawane (with Elisabeth Knust)
Crums paralogues and their functional significance in zebrafish epithelia. DST-DAAD Grant, April 2016 – March 2018

Vidita Vaidya
1. Role of epigenetic mechanisms in programming early adverse experience evoked vulnerability to psychopathology. DBT, Centre of Excellence in Epigenetics Award (Co-investigator: Sanjeev Galande, IISER Pune), 2016–2021
2. Self-fluorescent cell permeable glucose derived carbon nanospheres as a brain targeting vehicle: Implications in drug delivery and imaging. DBT-Translational Project (with Tapas Kundu, JNCASR), 2016–2019 (Rs. 50 Lakhs)
Supersonic Jet Spectroscopy

Strength of the N-H···N H-bonded complexes and Proton transfer process

While there have been numerous reports about the absolute strength of the O-H···O hydrogen bond, there have been no such report for the N-H···N. In the following project, we have considered a heterocyclic aromatic compound Benzimidazole (BIM) having N-H as part of the ring that can act as H-bond donor. Hydrogen bonded complexes of BIM with ammonia (Am), trimethylamine (TMA) have been reported earlier from our laboratory. The N-H stretching frequency red shift of hydrogen bonded complexes is generally used to comment on the relative strengths of these complexes. However, in the case of BIM-Am and BIM-TMA complexes due to severe interference from the NH bending overtones in the case of former and large number of CH stretches of TMA in the latter it was difficult to establish the true value of NH stretching frequency red shift in the respective complexes. In the following the experimental results on the deuterated analogs of Am and TMA complexes are presented that helped in identifying the true value of NH red shift. We have also determined the binding energy of the BIM-TMA N-H···N hydrogen bonded complex using photo-fragmentation spectroscopy.

The Benzimidazole N-H···N bound complexes with Am(d)1 and TMA(d)9 were formed using supersonic jet technique. The Resonantly Enhanced Multi-Photon Ionization (REMPI), Ion Depletion IR, and Photo-fragmentation Spectroscopy was used to probe these complexes.

Ion Depletion Infrared spectroscopy of BIM-Am-d3 and BIM-TMA-d9

In the experiments with ammonia, extensive proton exchange was found to take place between ND3 and BIM/H2O adsorbed on gas lines and the mass spectra showed multiple mass features ranging from 135 (BIM+NH3) to 139 (BIM-d+ND3). Therefore, ion depletion spectroscopy was the technique that was best suited to obtain the IR spectrum of BIM-am-d3. Masses of each of these features were carefully assigned. Our species of interest was m/z 138. The mass channel 138 will consist of complexes formed between BIM-d1 and am-d9, BIM-d1 and am-d9, and BIM-d2 and am-d1.

The Resonantly Enhanced Multiphoton Ionization (REMPI) spectrum of mass channel 138 showed multiple features due to the multiple species referred to above appearing in this channel. IR spectra were recorded by keeping the UV fixed at each of these features and scanning the IR frequency. The IR spectra recorded by keeping UV fixed at A(35897 cm⁻¹) and C(35920 cm⁻¹) showed dips at 3249 cm⁻¹, whereas the IR spectra recorded by parking the UV photon at B(35904 cm⁻¹), D(35926 cm⁻¹), and E(35934 cm⁻¹) did not show any dip. Only the peaks at A and C showed the characteristic red shifted NH transition. These could be due to two different isomers or they could be vibronic features of the same isomer. Therefore, it was concluded that the BIM(N-H) stretch for BIM-am-d3 appears at 3249 cm⁻¹, which was 270 cm⁻¹ red shifted from that of BIM (3519 cm⁻¹). [Viola C. D’Mello and S. Wategaonkar]

In case of TMA-d9 complexes no proton exchange was expected between TMA and BIM. The mass spectrum was clear and showed features at m/z 186 (BIM-TMA-d9), m/z 118 (BIM), m/z 69, and m/z 68. In addition some unexpected features were observed at 188, 120, 70 and 137. The masses 68 amu and 69 amu are charge transferred fragments (TMA+) and proton transferred (HTMA+) of BIM-TMA-d9. The REMPI spectrum of the mass channel 186 was recorded and the band origin of the complex was found to arise at 35806 cm⁻¹. The REMPI spectra of the peaks at 188 (186+2), 120 (118+2), 70 (68+2), and 137 (135+2) indicated that they arose from fragmentation of higher clusters in which a deuterium was transferred to the parent complex, BIM, TMA, and BIM-NH3 complex, respectively. The IDIR spectrum was recorded by keeping the UV fixed at the band origin and the broad feature centred at 35831 cm⁻¹. It showed a multiplet structure with an underlying broad feature in the region between 2900 cm⁻¹ to 3200 cm⁻¹. The multiplet structure appears to be due to fermi
resonances between the CH bends with the large number of C-H stretches of BIM moiety that appear in this region. The red shifted N-H-stretch has been calculated and is expected to appear in this region, however due to the overlap with the C-H stretch modes of BIM it is not possible to isolate this feature. [Viola C. D’Mello and S. Wategaonkar]

**Photo-fragmentation spectroscopy of BIM-TMA**

The binding energy of the BIM-TMA complex was determined by using the photo-fragmentation spectroscopy technique. Mass spectra were recorded at discrete wavelengths while keeping the laser pulse energy constant at each wavelength. The ratio of the BIM$^+$ fragment mass (118) to the sum of the parent and fragment mass was then plotted versus the photon energy to get the appearance potential of the BIM$^+$ fragment. From the appearance potential of the fragment BIM$^+$ and the known ionization potential of BIM, we were able to determine the binding energy of the BIM-TMA complex in the ground state to be 0.44 eV.

**Spectroscopic Identification and investigation of Novel hydrogen bonds**

Carbenes as hydrogen bond acceptors: Investigations of novel hydrogen bonds have been the primary focus of our research group in recent times. Carbenes are thought of as another class of novel hydrogen bond acceptors as these play important roles in unimolecular dissociations and are highly reactive species. Experimental investigations on these systems have been initiated. To begin with a few precursors of carbenes, such as sodium salt of di-phenyl-diazomethane are being synthesized. Another class of carbenes called Arduengo carbenes or N-heterocyclic carbenes are also being synthesized. [Pritam Kadam, A. Patil, and S. Wategaonkar]

**Electron spin polarization and relaxation**

**Photophysical quenching of excited states and electron spin polarization**

For the past few years, we have been studying the photophysics of molecular systems consisting of a chromophore moiety covalently linked to a 2,2,6,6 tetramethyl piperindine N-oxyl (TEMPO) free radical through a spacer group of different lengths. The general aim is to understand the mechanistic details of quenching of the excited states, when a well-defined distance separates the chromophore and the quenching free radical such that their translational diffusive motions are severely restricted. In order to examine the applicability of the general dynamical model, developed for naphthalene-TEMPO linked molecules, to other similar linked systems, we undertook synthesis of two series of linked molecules. For these two series, pyrene and anthracene are two different chromophore moieties covalently linked to TEMPO through spacer groups of different lengths. We succeeded synthesizing 5 different molecules of the pyrene series. Of the anthracene series, we now have two linked molecules. Their photophysical and electron spin polarisation studies showed that, for the pyrene linked-systems, sequential quenching of excited singlet and triplet states giving rise to spin-polarised time-dependent EPR signal of opposite sign, their magnitudes being strongly dependent on the length of the spacer group. In contrast, for freely diffusing pyrene and TEMPO without linking, showed quenching of predominantly the excited singlet state. For the anthracene-TEMPO linked molecule with the spacer group of a single –CH$_2$– moiety, sequential quenching of the excited singlet and triplet state were seen. In addition, we could also detect its excited quartet state at room temperature, which is rather uncommon. Detailed analyses of the time-evolution of these systems are in progress. [Alok Tripathi, Sushma Kundu, Ranjan Das]

We planned to add more molecules to our naphthalene-TEMPO linked systems synthesized earlier, so that the distance between the naphthalene and the TEMPO moieties could be steadily increased from the shortest possible distance. We also planned to study any possible role of the linking group in the quenching process. To that end, we have synthesized naphthalene-TEMPO linked molecules with ether and ester linkages. The synthesis of the molecule with the shortest distance between the two moieties is in progress. [Alok Tripathi, Sushma Kundu, Ranjan Das, Vinayak Rane (BARC)]
of the ubiquitin family proteins. Our study broadens the outlook of mechanical stability in proteins with a β-grasp fold to go beyond the ‘β-clamp’, hitherto considered as the sole contributor to their mechanical stability. Our study highlights the coupling of β-strands with α-helix as the next major contributor to mechanical stability of proteins of ubiquitin fold. [Mona Gupta, Ravindra Venkatramani, Sri Rama Koti Ainavarapu]

Biophysical studies on malaria parasite cell surface circumsporozoite protein (CSP)

Malaria remains a major cause of morbidity and mortality throughout the tropical world. Currently, the most effective vaccine candidate of malaria is based on the Plasmodium falciparum circumsporozoite protein (CSP), a major surface protein implicated in the structural strength, motility and immune evasion properties of the infective sporozoites. It is suspected that reversible conformational changes of CSP are required for infection of the mammalian host, but CSP’s detailed structure and dynamic properties remain incompletely understood, limiting our understanding of its function in the infection. Here, we studied the structural and mechanical properties of the CSP studied using single-molecule force spectroscopy on several constructs, one including CSP’s central region rich in NANP amino acid repeats (CSPrep) and a second consisting of a near full-length sequence without the signal and anchor hydrophobic domains (CSPΔHP). Our results show that the CSPrep is heterogeneous, with 40% molecules requiring virtually no mechanical force to unfold (<10 pN), suggesting these molecules are mechanically compliant and perhaps act as entropic springs, while the remaining 60% are partially structured with low mechanical resistance (~70 pN). CSPΔHP having multiple force peaks suggests specifically folded domains, with two major populations possibly indicating the open and collapsed forms. Our findings suggest that the overall low mechanical resistance of the repeat region, exposed on the outer surface of the sporozoites, combined with flexible full-length conformations of CSP, may provide the sporozoites not only with immune evasion properties, but also with lubricating capacity required during its navigation through the mosquito and vertebrate host tissues. These findings would further assist in the design and development of future malarial vaccines. We have also carried out motility assays on cellular slime-mold Dictyostelium discoideum cells expressing CSP on its surface. We observed that the elasticity and motility of these amoebic cells could be correlated with the amount of surface-expressed CSP. Our findings suggest that the overall low mechanical resistance of CSP may equip a sporozoite with flexible and pliable surface, thus providing a lubricating capacity required for its long and penetrating journey. Understanding the roles of the vaccine candidate CSP should aid us in better control of malaria. [Aditya Prasad Patra, Sri Rama Koti Ainavarapu and Shobhona Sharma]

**Reaction Dynamics**

The reaction dynamics group utilizes contemporary ultrafast optical spectroscopy techniques to establish a causal link between structural dynamics and reaction efficiencies in macromolecular systems. We have used ultrafast optical spectroscopy techniques to not only track reaction trajectories but also to generate synthetic strategies for stabilizing reactive intermediates within supramolecular architectures. One of the major highlights from the group recently has been a successful effort to understand the correlation of chemical structure affect and its manifestation of charge generation in organic semiconducting films. Using time-resolved Raman we collected vibrational snapshots of excitons relaxation in the conjugated polymer backbone. This remarkable result was published in Nature Communications and was highlighted in Nature Journal under “Excited States”.

[Palas Roy et al. Nature Communications (2017), 8, 1716]
Our work provides a molecular picture of charge generation efficiency and also a structure-function perspective for new polymer design.

Probing exciton and polaron dynamics in conjugated molecular systems

Optimizing the light trapping process and subsequent charge separation chemistry is at the heart of engineering efficient photon-conversion devices. Organic solar cells that have the best efficiencies are often fabricated by using donor-π-acceptor based conjugated polymers which makes them a viable alternative for cheap solar cell technology. However, to reach efficiencies closer to Silicon solar cell technology, it is necessary to understand all the necessary pathways by which exciton energy is lost in the conjugated backbone. We used femtosecond stimulated Raman spectroscopy to probe exciton relaxation and generation of hot CT states in the donor-acceptor backbone. We discovered that the π-bridge planarization leads to generation of the charge transfer character which allows for easier separation of charges in the organic semiconductors. [Palas Roy, Nita Ghosh, Siddhartha Sohoni, Gokul Anandan, Satish Patil (IISc Bangalore) and Jyotishman Dasgupta]

Separately we have also probed the charge generation dynamics in supramolecular donor-acceptor systems where the charge separated states are only long-lived once supramolecular structure is built. We are currently probing the charge transfer in large systems using femtosecond stimulated Raman spectroscopy with the aim of identifying reaction coordinates for charge separation. Currently we have recorded the first Raman transients which will help us identify the modes that need to be synthetically tuned to optimize the charge separation lifetime. [Nita Ghosh, Mahesh Hariharan (IISER TVM) and Jyotishman Dasgupta]

Probing Twisted Intramolecular Charge Transfer States

Our group has started probing Raman signatures of the twisted intramolecular charge transfer (TICT) state in small molecule mitochondrial-staining dyes. The TICT state is crucial in determining the polarity and viscosity sensitivity of the fluorescence dye. Recent femtosecond stimulated Raman spectroscopy measurements in our lab has unraveled an generic Raman signature of the TICT states in stilbazolium salts for the first time. We envision that this work will open up new ways of probing TICT dyes and optimizing them for commercial applications. [Shreetama Karmakar, Abhinandan Ambastha, Rohit Mann, Aditya Dharmadhikari, Jayashree Dharamadhikari, Akash Gulyani (NCBS-InStem), Ravindra Venkatramani and Jyotishman Dasgupta]

Charge Transfer Dynamics in Azurin

Azurin is an electron transfer metalloprotein whose role is to regulate the redox status of the membrane or soluble cellular components by transferring electrons from one cofactor to another. We have probed the intrinsic charge transfer reaction that occurs in the active site of the copper protein Azurin. The efficiency of the CT reaction actually is critically dependent on the ligand environment the Cu²⁺ ion is in. Mutation of a distant cysteine which stabilizes the protein structure, however shows affect the Copper binding site. This surprising result motivated us to address the CT reaction using time-resolved optical spectroscopy especially monitoring the vibrations. We are currently developing impulsive excitation methods as well as using femtosecond stimulated Raman spectroscopy to probe the coordination environment sensitively. [Soumyajit Mitra, ASR Koti, Jyotishman Dasgupta]

Photoswitching the aggregation morphology in dipeptides

We discovered that F-F dipeptide aggregation pathway can be modified by attachment of an azo-group on the phenylalanine side-chain. We carried out surface-enhanced Raman spectroscopy to quantify the monomer and the aggregates: fibrils and vesicles. In the trans-configuration of the Azo group the AzoF-F dipeptide easily forms fibrils at high concentration. Under UV-illumination at 450 nm these fibrils can form vesicles and while under 365 nm illumination, they can be reversibly switched back to fibrils. However the entire aggregation process is stopped if the Azo group is switched to cis configuration in monomeric condition. [Melby Johnny, K. Vijayalakshmi, Palas Roy, Ankita Das, Aseem Mishra (ICGEB Delhi) and Jyotishman Dasgupta]

Carotenoid Biosynthesis

Carotenoids are an important class of polyene pigments that are taken up by the photosynthetic apparatus to form protein-pigment complexes. We are currently working to understand the metabolic regulation of all-trans-lycopene in photosynthetic organisms which is
controlled enzyme CRTISO. It has been reported that light can rescue the impaired CRTISO activity if mutated in the chloroplasts. The efficiency of the light induced pathway therefore becomes important to quantify. We recently demonstrated that prolycopene aggregates in model liposomes can react with high efficiency due to increased triplet generation. In addition, we have investigated the conformational propensities of the FAD molecule in a confined environment. Our FAD in confinement work should enable a molecular understanding of the events leading to isomerization of prolycopene by the enzyme CRTISO. [K. Vijayalakshmi, Arup Kundu and Jyotishman Dasgupta]

Singlet Fission in Organic Materials

Multi-exciton generation is an important pathway by which short circuit current of the solar cell can be increased. We found a way to generate ultrafast singlet fission process in diketopyrrolopyrrole-based molecular nano-aggregates. This methodology of packing the molecules led to 130% efficiency of triplet generation per 100 photons although theoretically it is predicted to be 200%. Using transient absorption spectroscopy in combination with steady state Raman, absorption and emission measurements we show that within 700 fs triplet-pair states are generated which dissociate in ~10 ps to free triplets. [Palas Roy, Nita Ghosh, Srikant Kumar Sethi, Satish Patil (IISc Bangalore) and Jyotishman Dasgupta.]

Visible Light Photochemistry inside Molecular Nanocages

Combining the idea of generating optically allowed delocalized host-guest CT states with reactive confinement provided by molecular cages, a new visible light photochemistry strategy has been pioneered by our group. Using a well-defined metal-organic nanocage as a delocalized electron acceptor, we have formulated an efficient chemical scheme to carry out ultrafast hydrogen abstraction reactions from organic substrates in water. In continuation with this idea this year, we showed that C-H bond activation can be performed on benzyl-aromatics with high specificity. Future goals include carrying out cascade reactions which would lead to single step reactions in a complex organic backbone. [Ankita Das, Souvik Ghoshal, Sunandita Paul and Jyotishman Dasgupta]

Theoretical Chemical Sciences

Demonstration of optical charge transfer spectra in all naturally occurring charged amino acids in protein folds

Building on our discovery last year of a new optical charge transfer band in the UV-Visible spectra of proteins, we have shown this year that all naturally charged amino acids occurring in the biological context show facile spatial separation of electronic charge upon absorbing UV-Visible light. We have further shown that such excitations can serve as spectroscopic markers to track structure and dynamics of proteins in solution phase. [Ravindra Venkatramani]

Computational framework to design peptide based probes to image phospholipid-protein interactions on cell membranes

We have setup a systematic computational framework to predict the optimal placement of optical dyes on small peptides to sense structural transitions induced upon binding to cellular membranes. Our chemical biology collaborators at TIFR have demonstrated the design principle in the lab. [Ankona Datta, Ravindra Venkatramani]

Capturing the structure of transient intermediates along the mechanical unfolding pathways of a metalloprotein

Using steered molecular dynamics simulations we have provided high resolution views of the structural changes occurring during the mechanical unfolding of azurin, a copper containing metalloprotein. Specifically, we show the presence of copper metal ion changes the unfolding pathways of the protein without altering its stability. Our modelling studies support complementary experimental Atomic Force Microscopy (AFM) studies on azurin carried out at TIFR. [A. S. R. Koti, Ravindra Venkatramani]
Molecular Biophysics

Novel Pure Shift NMR Methods and Their Applications

Solution state NMR plays an important role in structural studies of small organic molecule mixtures and proteins. However, more often severely overlapped \(^1H\)-\(^1H\) scalar couplings present in the inherent limited \(^1H\)-NMR chemical shift range (~10 ppm) significantly hampers the spectral resolution and that makes the chemical shift analysis difficult. In order to circumvent this issue, different advanced versions of PSYCHE/ZS-homodecoupling (pure shift NMR) methods have been developed, i.e., NUS-PSYCHE-TOCSY, PS-CLIP-COSY, Hadamard-PSYCHE-TOCSY, CPMG-PSYCHE/Inversion Recovery (IR)-PSYCHE, for unambiguous chemical shift assignments and to monitor the drug-protein interactions. Additionally, for the simultaneous determination of \(^1H\)-\(^1H\) and \(^1H\)-\(^19F\) scalar couplings in complex steroid molecules, a homodecoupled diagonal-2D experiment, F1-PSYCHE-DIAG has also been developed. On the other hand, to recover the homonuclear scalar coupling information that decouples in the pure shift NMR, two different variants of pulse sequences, viz., selective coupling reintroduction in pure shift (SCRPS) and J-scaled pure shift (JSPS) experiments are designed; wherein, the earlier one maps complete scalar coupling spin network of complex organic molecules and the latter one facilitates the measurement of valuable long range scalar coupling information at ultra-high resolution. The applications of pure shift NMR methods are not only limited to small molecules, and they have been extended for the sequential acquisition of two HSQC spectra (\(^13C\)-HSQC of small molecules and \(^15N\)-HSQC of proteins) in a single NMR experiment (PRO-SMASH-HSQC2). This method permits monitoring the drug-protein interactions at atomic levels and will have a potential applications in drug discovery programs. [Veera Mohan Rao K. and R. V. Hosur]

NMR in Herbalomics

It is becoming apparent in recent times that herbal medicines are useful for treating a number of ailments, and these have much less side effects compared to their allopathic counterparts. Herbal preparations have many constituents which seem to work in a synergistic manner, and thus a particular preparation is able to cure many seemingly unrelated diseases; presumably, different components of the preparations are responsible for different activities and because of the synergy between them, the side effects are likely to be reduced. We have termed here this area of science dealing with systematic characterization of the effects of variety of herbal preparations, on various metabolic pathways, diseases etc, as ‘HERBALOMICS’. As of now, detailed scientific investigations with proper controls and precise descriptions of the variety of herbal preparations that are being used discretely without proper quantitation by the ‘Ayurvedic Vaidyas’ are lacking, which is why, this line of treatment is yet to receive general acceptance among the medical community. We have initiated a detailed study of various aspects of a variety of herbal preparations using NMR which is the most powerful tool for characterizing structures and interactions of molecules in solution. [Mandar Bopardikar, Kavitha Rachineni, R V Hosur]

Materials Chemistry

Inorganic Vanadates as viable electrodes for supercapacitor applications

Our work with BiVO\(_4\) has continued over the past year. The research has concentrated on the direct effect of visible radiation during the electrochemical charging and discharging of a battery. To elaborate, storage of solar radiation is currently accomplished by coupling two separate devices, one that captures and converts the energy into an electrical impulse (a photovoltaic cell) and another that stores this electrical output (a battery or a supercapacitor electrochemical cell). This configuration however has several challenges that stem from a complex coupled-device architecture and multiple interfaces through which charge transfer has to occur. As such work over the past year concentrated on employing a scheme whereby solar energy capture and storage are coupled using a single bi-functional material. Two electroactive semiconductors BiVO\(_4\) (n-type) and Co\(_3\)O\(_4\) (p-type) have been separately evaluated for their energy storage capability in the presence and absence of visible radiation. Each of these
have the capability to function as a light harvester and also they have faradaic capability. An unprecedented aspect has been observed in that upon photo-illumination of either of these semiconductors, \textit{in situ} charge carriers being generated play a pivotal role in perturbing the electroactivity of the redox species such that the majority charge carriers, \textit{viz.} electrons in BiVO$_4$ and holes in Co$_3$O$_4$, influence the redox response in a disproportionate manner. More importantly, there is an enhancement of \textit{ca.} 30% in the discharge capacity of BiVO$_4$ in the presence of light and this directly provides a unique route to augment charge storage during illumination. [Y. Arora and D. Khushalani]

**Novel luminescent Carbon Nanodots**

High quantum yield, photoluminescence tunability, and sensitivity to the environment are the few distinct trademarks that make carbon nanodots (CDs) interesting for fundamental research with potential to replace the prevalent inorganic semiconductor quantum dots. Currently, application and fundamental understanding of CDs are constrained because it is difficult to make a quantitative comparison among different types of CDs simply because their PL properties are directly linked to their size distribution, the surface functionalization, the carbon core structures (graphitic or amorphous) and the number of defects. Over the past year we have worked upon a facile one-step synthesis of mono-dispersed and highly fluorescent nanometre size CDs from a ‘family’ of glucose-based sugars. These CDs are stable in aqueous solutions with photoluminescence in the visible range. Our results show several common features in the family of CDs synthesized in that the fluorescence, in the visible region, is due to a weak absorption in the 300-400nm from a heterogeneous population of fluorophores. Fluorescence quenching experiments suggest the existence of not only surface-exposed fluorophores but more importantly fluorophores present within the core. Interestingly, time-resolved fluorescence anisotropy experiments directly suggest that a fast exchange of excitation energy occurs that results in a homo-FRET based depolarization within 150ps of all the fluorophores. [D. Sasi and D. Khushalani]

**Evaluation of novel Perovskite based light absorbers for use in heterojunction solar cells**

Over the past year we have continued our work on hybrid perovskites as a intriguing photovoltaic material. A systematic study of a new hybrid organic-inorganic material where the cation has been replaced with imidazolium has been done. Imidazolium lead iodide (ImPI) shares the same stoichiometry of ABX$_3$ as a perovskite, however, it has a hexagonal structure. This material shows a vastly improved thermal stability as compared to the more popular hybrid perovskite, methyl ammonium lead iodide (MAPI). ImPI also exhibits a dramatic phase stability as compared to MAPI as demonstrated by the variable temperature XRD data (both low temperature and high temperature). In addition to the enhanced thermal robustness, ImPI shows three times better stability than MAPI under ambient conditions. The stability can be attributed to better packing efficiency of the ImPI lattice which in turn depends on the symmetrical and bulkier organic cation, imidazolium. [C. Seth and D Khushalani]

**Nanotubes vs Spheres: Optimizing Drug Delivery Vehicles**

Functional biomaterials can be used as drug loading devices, components for tissue engineering or as biological probes. As such, the design, synthesis and evaluation of a variety of local-drug delivery structures has been undertaken over the past few decades, with the ultimate aim of providing materials that can encapsulate a diverse array of drugs (in terms of their sizes, chemical compositions and chemical natures (i.e. hydrophilic/hydrophobic) and so forth). Moreover, predominantly only spherical capsules have thus far been evaluated (with chemical composition ranging from polymeric based PEG structures to hollow capsules of inorganic materials such Au, Fe$_2$O$_3$, SiO$_2$, TiO$_2$ and carbon allotropes). The morphology (along with size and surface chemistry) of these carriers is known to dictate the mechanism of cell internalization and the efficacy with which a drug can be released. Work over the last year has concentrated on the evaluation of specifically 1D structures consisting of NTs of HAp and their efficacy for cellular internalization using and hydrochloride as the model drug. The delivery potential of the drug/dye loaded HAp NTs in comparison with standard nanoparticles against CHO, the ovarian cell line; HeLa, the cervical cancer cell line; MG63, the osteosarcoma cell line and skin fibroblast primary cells were used for this model study. Importantly, it has been observed through this work that HAp NTs consistently showed dramatically higher drug loading capacity as compared to HAp NSs.
whilst having also better efficacy with respect to cell internalization/encapsulation. Furthermore, there were no deleterious effects observed by changing the carrier morphology on cell viability and in fact when NTs were loaded with DOX, the HeLa cell viability was consistently lower (by ca. 10-50%) than when pure DOX was introduced to HeLa cells. [B. Chandanshive and D. Khushalani]

Chemical Biology and Molecular Imaging

Optical sensors for tracking phospholipid induced conformational changes in phospholipid binding peptides

Membrane phospholipids play crucial roles in cytoskeletal rearrangement processes by mediating the regulation of actin polymerization. The signaling phospholipid Phosphatidylinositol-(4,5)-bisphosphate (PI(4,5)P2) controls the association and dissociation of actin binding proteins (ABPs), thereby acting as a key effector of actin polymerization and de-polymerization. Previous studies have shown that ABPs have specific PI(4,5)P2 binding motifs that undergo coil-helix transition upon binding to PI(4,5)P2. However, techniques such as circular dichroism (CD) and nuclear magnetic resonance (NMR), used previously to monitor conformational changes in ABPs required PI(4,5)P2 concentrations much higher (> 100 µM) than the biologically relevant concentration range (1-20 µM) of PI(4,5)P2. We asked if coil-helix transitions in the phospholipid binding motif of ABPs can be induced by biologically-relevant concentrations (1-20 µM) of PI(4,5)P2 by utilizing a sensitive fluorescence based approach, involving Förster resonance energy transfer (FRET). In our FRET studies, we chose a 20 residue PI(4,5)P2 binding peptide from an ABP Gelsolin, as in vitro model system for monitoring the coil-helix transition upon binding to PI(4,5)P2. Molecular Dynamics (MD) simulations guided the incorporation a suitable FRET pair – tryptophan and IAEDANS at specific locations on the peptide to provide contrasting FRET efficiencies in the coil and helix conformational states of the peptide. In both steady state and time resolved fluorescence experiments we observed an enhancement in the donor to acceptor energy transfer efficiency with increasing concentration of PI(4,5)P2 indicating a PI(4,5)P2 induced coil to helix transition. Importantly, both pure PI(4,5)P2 micelles, and vesicles containing 20 to 50 mol % of PI(4,5)P2, were found induce the peptide coil-helix conformational change. Our studies demonstrated that even sub-stoichiometric levels of PI(4,5)P2 in the 2.5-5 µM concentrations range could induce conformational changes in the Gelsolin derived peptide. [Ankona Datta, Samsuzzoha Mondal, Amitava Chandra, Ravindra Venkatramani]

Metal ion selective chelators for alleviating metal induced oxidative stress

Copper ions are essential for biological function yet severely detrimental when present in excess. Hence, biological systems have tight regulatory machineries that maintain copper balance in vivo. Any disruption in the homeostatic machinery can lead to pathophysiological conditions and excess copper has been associated with Wilson’s disease and multiple neurodegenerative conditions. At the molecular level, copper ions react with hydrogen peroxide to produce hydroxyl radicals that can irreversibly alter essential biomolecules. In the biological milieu, this reaction is catalyzed by excess labile copper ions predominantly bound to available biological ligands, modified proteins, and peptides that are upregulated during pathophysiological conditions. Hence, selective copper chelators that can remove excess copper ions and alleviate oxidative stress will help assuage copper-induced diseases. The challenge is to build chelators that can bind to copper ions with high affinity yet leave the levels of other essential metal ions unaltered. Most importantly, enzyme bound copper should remain unaffected. We have designed and developed Cu²⁺ selective chelators that have pM affinities to Cu²⁺, do not remove Cu²⁺ from enzymes, and have 8 fold (10⁸) higher affinities toward Cu²⁺ compared to other biologically relevant metal ions. We have shown that the chelators provide distinct protection against copper-induced oxidative stress in vitro and in live cells. Finally, we have taken the chelators a step forward by testing them in live zebrafish larvae which are established vertebrate models for studying oxidative stress and shown that the chelators can provide efficient protection against copper-induced oxidative stress in vivo. [Ankona Datta, Ananya Rakshit, Kaustav Khatua, Peter Comba (University of Heidelberg)]
Reversible colorimetric sensor for detection of mercury

We serendipitously discovered of an optical mercury sensor while trying to develop a water-soluble manganese probe. The sensor is based on a penta-aza macrocycle conjugated to a hemicyanine dye. The penta-aza macrocycle earlier designed in our group was used to develop photo-induced electron transfer (PET) based ‘turn-on’ fluorescent sensors for manganese. In an attempt to increase the water-solubility of the manganese sensors we changed the dye from BODIPY to hemicyanine. The resultant molecule afforded a distinct reversible change in absorption features and concomitant visible color change upon binding to Hg$^{2+}$ ions leading to a highly water-soluble mercury sensor with a 10 ppb detection limit. $^{1}$H-NMR studies demonstrated that a conformational change in the chromophore upon Hg$^{2+}$ binding led to the absorption spectral changes. The molecule also acted as an ‘ON-OFF-ON’ fluorescent sensor for Hg$^{2+}$ and we demonstrated its applicability for detecting Hg$^{2+}$ in living cells and in live zebrafish larvae using confocal fluorescence microscopy with visible excitation. High selectivity and sensitivity toward Hg$^{2+}$ detection makes the molecule an attractive probe for detecting Hg$^{2+}$ in contaminated water sources which is a major environmental toxicity concern. [Ankona Datta, Sayani Das, Anindita Sarkar, and Ananya Rakshit]

Molecular dynamics guided design of optical probes for imaging transient signaling phospholipids in vivo

Phospholipids are principal components of the cell membrane, but not mute structural spectators. These essential lipids regulate vital life processes. Phosphoinositides, a class of seven structurally distinct phospholipids that have differentially phosphorylated inositol headgroups, constitute a minor 2% of the eukaryotic membrane phospholipids. However, in terms of function, phosphoinositides play a singularly major role in mediating cell signaling processes. Crucial cellular processes including membrane trafficking routes like endocytosis and exocytosis, cytoskeletal rearrangement, nuclear events, mitogenesis, and ion channel transport are regulated by phosphoinositides. The importance of phosphoinositides in life processes is further underscored by the fact that previously unpredicted signaling roles and cellular functions of these phospholipids are being discovered and proposed with extraordinary rapidity. Most of the cellular functions mediated by phosphoinositides are achieved via interactions of lipid headgroups with peripheral and cytosolic proteins. Dynamic changes in phosphoinositide concentrations, locations, and distributions on membranes are proposed to act as initiating flags for signaling events. When phosphoinositide distribution changes, so does the signal. Therefore, visualizing phosphoinositide dynamics in living systems will provide that ultimate access to understanding key steps in the initiation and regulation of critical signaling pathways and membrane trafficking processes. In this emerging context, optical probes for visualizing phosphoinositides in living cells and organisms will be vital tools for monitoring phosphoinositide dynamics. The major gap in the area of phosphoinositide detection in living systems lies in the scarcity of cell-permeable and reversible chemical tools for visualizing phosphoinositides.

We have addressed these requirements by developing short peptide based optical sensors that have been designed based on insights obtained from molecular dynamics simulations performed to scrutinize the molecular basis of phospholipid membrane-peptide interactions. The sensors afford an emission blue shift and up to 70 fold enhancement in fluorescence emission upon binding to phosphatidylinositol-4,5-bisphosphate(PI(4,5)P2), the most crucial member of phosphoinositide family. We have successfully captured PI(4,5)P2 distribution and its agonist induced depletion events in live cells. Moreover, we have applied the sensors in a live multicellular model organism, Caenorhabditis elegans, and imaged PI(4,5)P2 within their nervous system. The phosphoinositide sensitive probes have thus been validated successfully both in live cells and in vivo. [Ankona Datta, Samsuzzoha Mondal, Rajasree Kundu, Amitava Chandra, Akshay Kapadia, Ravindra Venkatramani, Sandhya Koushika, Andrey Klymchenko (CNRS, France)]
Nano-catalysis

DFNS/Au as Enzyme

Mimicking enzymatic activity is a challenging task. Herein we report a dendritic fibrous nano-silica (DFNS) supported gold (Au) nanoparticles (DFNS/Au) as peroxidase like artificial enzyme.

It showed superior enzymatic activity for 3,5,3’,5’-tetramethylbenzidine (TMB) oxidation as a model reaction, significantly better than natural horseradish peroxidase (HRP) enzyme as well as other reported nanomaterials based artificial enzymes. A solvent dependent selectivity towards two-electron oxidation product, TMB-diamine, has also been observed. This study clearly indicates the vital role of fibrous morphology and unique silica channels of DFNS for enhancement in enzymatic activity. [R. Singh, R. Belgamwar, M. Dhiman, V. Polshettiwar]

Self-Assembled DFNS as Photonic Crystals

Photonic crystals are essentially a periodic (‘crystalline’) arrangement of dielectric nanoparticles that respond in unison to incident light. They can be used to harvest light in various applications such as photocatalysis, solar cells and lasing. In this work, we prepared photonic crystals of dendritic fibrous nanosilica (DFNS), by their self-assembly.

Due to the narrow particle size distribution of the as-synthesized DFNS, they readily formed colored photonic crystals. The photonic band gap was found to be tunable by using DFNS of various sizes, and fiber density. Notably, even after having similar particle sizes (but with different fiber density), they showed different photonic band gaps, indicating that the fiber density plays a role in the band gap of photonic crystals. Such observations are not reported before. This can be arising from the difference in their refractive index due to difference in their fiber density and hence vari-ation in silica content, leading to a different optical signature. [Ayan Maity, Sushil Mujumdar, Vivek Polshettiwar]
Crystal Clear Nano-TiO2

Perfect crystallization of active sites in supported TiO₂ photocatalysts is still a challenge. In this work, we report new photocatalyst design by unique combination of nanomaterial morphology and active site crystallization protocol.

This yielded nano-TiO₂ based photo-catalysts with one of the highest reported photocatalytic hydrogen yield.

Wrinkled Carbon Cages

In this work, we reported the synthesis protocol for carbon coated dendritic fibrous nanosilica (DFNS@Carbon) and high surface area wrinkled carbon nanospheres using phenol formaldehyde polymerization chemistry. We have shown that the choice of hard template, i.e. DFNS with different sizes and fiber density, can lead to the synthesis of carbon-coated DFNS and wrinkled carbon nanospheres with tunable properties, having high surface area (1090 ±50 m²/g), large pore volume (1.18 ±0.02 cm³/g) and distinct pore size distribution (from 3.5 nm to 15 nm).

Bioinorganic Chemistry

Designing mono-nuclear copper center in the subunit II of cytochrome c oxidase

The CuA center in the subunit II of the respiratory enzyme, cytochrome c oxidase consists of a binuclear copper center with a Cu₂S₂ core. Our group has been involved in deciphering the pathway of insertion of copper ions into the protein and mechanism of formation of the binuclear metal center. Our earlier studies on peptide-mimetics of metal binding intermediates suggested that there are multiple mono-nuclear copper species formed in the pathway of formation of the binuclear center in the protein. One of the two cysteine residues may play important role along with the histidine in the metal ion binding loop of the protein in the initial stage of sequestering one copper ion and transporting it into the protein matrix. In order to stabilize the possible mononuclear copper center at the metal binding site of CuA, we have designed two mutants of the proteins, which are expected to mimic the proposed intermediated of copper binding pathway. The mutant C153P/L155H/H157A CuA designed to remove one of the cysteine and change the location of the histidine residue in the metal ion binding loop so that a single copper ion binds to the metal ion binding site of the protein instead of two copper ions. The mutant proteins were made and characterised by various spectroscopic methods. CD results suggest that mutation of Cys153 increased the beta sheet content of the protein from ~44% to ~60% suggesting that the metal ion binding loop possibly becomes smaller in the mutant similar to that expected for a mono nuclear copper ion binding protein. UV-visible spectrum of the C153P mutant of CuA exhibited peaks at ~460nm, ~580nm and ~730nm similar to that of AcnP, a naturally existing green copper protein. Previous stopped flow studies by us suggested that the mononuclear intermediate formed during apo- to binuclear holo- CuA formation is indeed a “green” copper center. Cyclic voltammetric studies showed the E₁/₂ of the C153P CuA mutant as +336 mV (vs NHE) while that of the C153P/L155H CuA double mutant was found to be 308.5mV (vs NHE). These result suggested that mutation of cysteine 153 indeed leads to formation of a green copper species and second mutation of L155H causes changes in the geometry of the metal binding site leading to decrease in the redox potential. [Dwaipayan Dutta Gupta and S. Mazumdar]

State saturation mutagenesis of CYP175A1

In order to modify the substrate binding site of the thermostable enzyme CYP175A1, we chose certain amino acids that may be important at the substrate binding site of the enzyme and designed state saturation
mutagenesis (SSM) instead of classical site directed mutagenesis. In SSM, we mutate one residue by all other 19 amino acids. We designed degenerative primers for saturation mutant library construction of CYP175A1. Here, we have designed NNK degenerative primer rather than NNN or other possible combinations as the theoretical expression of all 20 amino acids using only 31 codon and 1 stop codon only possible in NNK and NNS. In preliminary studies, we optimized the PCR conditions like annealing temperature, MgCl2 concentration, oligonucleotides concentration, reaction buffer, dNTP’s concentration, template concentration etc. After that, we have prepared a large mutant library of CYP175A1. We confirmed these mutant libraries through sequencing. We designed five different primers to get complete sequencing for confirmative randomization of amino acids. After sequencing, theoretically we analyzed the chromatogram and calculated the area covered by mutated nucleotides by fitting of chromatogram of NNK position. We have identified that most of the mutant libraries were properly randomized suggesting that there will be a high probability of getting all amino acid mutant containing colonies during transformation. [Manish Shandilya, Mohd Taher and S. Mazumdar]

**Subcloning of the CYP175A1 nd its redox partners**

We subcloned CYP175A1 in pRSFDuet-1 vector, and its electron donor partners Ferredoxin (FDX) and Ferredoxin NADH reductase (FNR) were cloned in pET Duet-1. These two vectors are compatible cloning vectors and have different origin of replication and different antibiotic selection markers. For co-expression of all three proteins in a single E.coli cell, we optimized the concentration of plasmids for co-transformation and we carried out all co-transformation using 2 µl of each plasmid of 50ng/µl concentration to get sufficient colonies for activity analysis. We also optimized the condition of co-expression in 96 deep well plates of the two vectors and used 37C/200rpm for growth and expression after IPTG induction. After co-expression of mutant with FNR-FDX, we performed the activity analysis in the cell lysate. This has made stage for high throughput screening of the library of mutants of the enzyme. [Manish Shandilya, Mohd Taher, and S. Mazumdar]

**Optimization of apo-CYP175A1 preparation**

Preparation of apo-form of cytochrome P450 is more challenging due to its large structure and high molecular weight than that of small enzymes such as myoglobin. We have optimized the preparation protocol of apoenzyme for CYP175A1. The first approach to make apo-CYP175A1 was by direct expression of CYP175A1 in minimal media. Incomplete apo-CYP175A1 was observed, i.e. small but significant amount of holo-CYP175A1 expression was observed. Therefore, we opted to remove the heme- from holo-enzyme to make apo-CYP175A1 by lowering the pH of holo-CYP175A1. We have modified Teale’s method of heme-extraction as following: a multiple times of solvent extraction was carried out to ensure the complete removal of heme form holo-CYP175A1. During the dialysis against buffer even at very low strength (20mM, 7.4 pH), apo-CYP175A1 is prone to be precipitated out of the solution. We have dialyzed against water was done to prevent the precipitation. The proper folding of apo-CYP175A1 is confirmed by circular dichroism spectra at far UV region, which is identical with holo-CYP175A1. [Abhijit Mondal and S. Mazumdar]

**Preparation of hybrid CYP175A1 with non-natural porphyrins and asymmetric catalysis using hybrid enzymes as catalyst**

To carry out abiological catalysis by proteins, we have prepared hybrid proteins by reconstituting myoglobin and apo-CYP175A1 with various unnatural metalloporphyrins (such as Cobalt (II) protoporphyrin (CoPPIX), Iridium protoporphyrins(IrPPIX), etc. Purified hybrid proteins are investigated for stereoselective catalysis. We have been studying the stereoselective cyclopropanation reaction between styrene and ethyl diazoacetate (molar ratio of 1:3) using hybrid proteins (10 mole %). Flame ionization detector coupled with gas chromatography is used to analyze the reaction mixture. The catalysis with native myoglobin and Cobalt Myoglobin showed ethyl trans-2-phenylcyclopropanecarboxylate predominantly, but ethyl cis-2-phenylcyclopropanecarboxylate was formed predominantly with Iridium Myoglobin and Ir-CYP175A1. Further optimization of reaction conditions are in progress. [Abhijit Mondal, Mriganka Das and S. Mazumdar]

**Study on a novel non-enzymatic fragmentation of CYP175A1**

Although theoretical half-life of an amide bond is very high in several years, amide bonds become unstable below pH of 2 and above the pH of 11, which leads to the cleavage of amide bonds in peptides and protein.
We have identified the non-enzymatic cleavage of amide bonds in CYP175A1 upon keeping the enzyme in room temperature for longer period of times. A discrete fragmentation pattern was observed in SDS-PAGE for CYP175A1. Two intense fragmentation bands in between 16 and 29kDa marker bands are observed. We have identified the two major large sequences of fragments by liquid chromatography-mass spectrometry (LC-MS). The cleavage of amide bond between arginine (184R) and lysine (185K) is responsible for the 23kDa (exactly 23312.98Da) band in SDS-PAGE. Mass of the another fragment in between 16 and 29kDa was detected as 20034 Da, which was due to cleavage of amide bond between serine (213S) and glutamic acid (214E). It was interesting to notice that both amide bonds were in the structured region (here in Helix12 and Helix15 respectively). We are currently trying to identify small sequences of fragments as well to understand the origin of such nonenzymatic cleavage of enzyme. [Abhijit Mondal and S. Mazumdar]

**Encapsulation of enzymes (CYP175A1 and myoglobin) inside metal organic frame-work (MOF) to increase the stability and activity**

After discovering the auto-fragmentation in CYP175A1, we wanted to improve the stability of protein and harness its activity even in harsh condition (such as organic solvents, high temperature). Protein inside the cell is stable and in the most active form. This may be because of the confinement of protein in either cytoplasm or at cell membrane, which restricts their Brownian motion. Inspired from the in-cell stability of protein, we introduced metal organic framework as a cage to the proteins. We have incubated the proteins with MOFs, thus the protein encaged inside the porous network of the MOF. We have prepared Zinc Imidazole Framework-8 (ZIF-8) to encapsulate the enzyme inside it. [Mriganka Das, Abhijit Mondal and S. Mazumdar]

**Electro-catalytic properties of cytochrome P450 immobilized on carbon nanotubes**

We used edge plane pyrolytic graphite electrode for the conjugation of cytochrome P450cam mutant on electrode for biocatalytic degradation of pesticides. The conjugation of carbon nanotube modified with pCPMI on the electrode by electrostatics was achieved. Subsequently, we immobilized of the enzyme on the MWCNT-pCPMI conjugated graphite electrode and characterised the construct by various methods. Electro catalysis of the reaction of dieldrin by this enzyme –nanotube assembly on the electrode is being investigated. [Ramiz Yusuf Sheikh, and S. Mazumdar]

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**Members**


**Visiting Fellows**

Mriganka Das, Pritam Kadam, Shreeta Karmakar, Kaushalendra Kumar (till August 2017), Manish Shandilya (Till October 2017), Jyoti Singh Tomar, Alok Kumar Tripathi

**Senior/Junior Research Fellows/Research Associates**

Pragya Chopra (till Oct. 2017), Akshay Kapadia, Ramiz Sheikh, Priya Yadav

**Research Scholars**

Scientific & Technical Staff

Administrative Staff
Shashikant K. Kadam, Jayesh Malkan

National and International Involvement

Ranjian Das
Member, Editorial board of ChemPhotoChem, a journal published on behalf of ChemPubSoc Europe

Jyotishman Dasgupta
1. Editor, Scientific Reports (Nature Publishing Group)
2. Joint secretary, Fluorescence Society
3. Member, Indian Biophysical Society
4. Member, American Chemical Society

Ankona Datta
1. Member, Fluorescence Society
2. Member, Indian Biophysical Society
3. Member, American Chemical Society
4. Council member of the Materials Research Society of India, Mumbai Chapter

R. V. Haser
1. Chairperson, INSPIRE Faculty Selection Committee
3. Academic Board, UoM-DAE CBS, 2009–2017
4. Member, DAE-SRC young scientist award committee
5. Founding member, Fluorescence Society, India

Sudipta Maiti
1. Member, Editorial Board, Biomedical Physics and Optics Express, IOP Publishers, UK
3. Member, Editorial Board, Frontiers in Physiology and Biophysics, Nature Publishing Group
4. Chairman, Fluorescence Society, March 2016 – present
5. Member, Scientific Advisory Committee, National Brain Research Centre, Manesar, Haryana
6. Secretary, Indian Biophysical Society, March 2017 – present

Shyamalava Mazumdar
1. Life member, Chemical Research Society of India
2. Life member, Indian Biophysical Society
3. Steering Committee Member, Asian Biological Inorganic Chemistry
4. Member, National Organising Committee, Modern Trends in Inorganic Chemistry
5. Member, Society of Biological Inorganic Chemistry
6. Member, Syllabus Committee, University of Mumbai
7. Member, NASI Young Scientist Award Selection Committee
8. Member, NASI Fellowship Scrutiny Committee
10. Member, Council, International Society of Magnetic Resonance (ISMAR), 2014–present
11. Member, Scientific Advisory Committee of ISMAR, 2014–present
12. Member, DBT task force on Modern Biology, 2014
13. Elected ISMAR Fellow, 2017

Deepa Khushalani
1. Member, Chemical Research Society of India
2. Member, Materials Research Society (USA and India)
3. Fellow, Royal Society of Chemistry

A. S. R. Kazi
1. Life member, Indian Biophysical Society
2. Member, The American Society for Biochemistry and Molecular Biology, USA
3. Member, Biophysical Society, USA
4. Founding member, Fluorescence Society, India

Vivek Polshettiwar
1. Chair, Conference on Advances in Catalysis for Energy and Environment, TIFR, Mumbai 10–12 Jan. 2018
2. Thesis examiner and thesis vivo-vice external examiner of various IITs, CSIR laboratories and universities
3. Member, Executive Committee of Society for Materials Chemistry (SMC)
4. Member, Executive Committee of RSC Chemical Nanosciences and Nanotechnology

Ravindra Venkatramani
1. Life Member, Indian Biophysical Society
2. Fellow, Royal Society of Chemistry
3. Secretary, Royal Society of Chemistry, West India Section
4. Member, Editorial Board, Scientific Reports (Nature Publishing Group)
5. Member, Editorial Board, Journal of Biosciences
6. Reviewer, Austrian Science Fund

Sanjay Wategaonkar
1. Associate Editor, Journal of Chemical Sciences (Springer), Indian Academy of Sciences, Bangalore (May 2015 – to date)

Visits

Sudipta Maiti
University of New South Wales, Sydney, April 17–18, 2017
(Invited for discussions with the faculty of the new Single molecule Center there)

Ravindra Venkatramani
Großbothen, Germany (to attend Indo-German Workshop),

Invited Talks

Ranjan Das
Insight into Photophysical and Photochemical Dynamics through Electron Paramagnetic Resonance Spectroscopy. 14th DAE-BRNS Biennial Trombay Symposium on Radiation and Photochemistry, Trombay, 3–7 January 2018

Jyotishman Dasgupta
1. Ultrafast bridge planarization in donor-π-acceptor copolymers drives intramolecular charge transfer. FCS2017 meeting, IIT Guwahati, December 2017
2. Tracking ultrafast bridge planarization in donor-π-acceptor copolymers. 26th National Laser Symposium meeting at BARC, India, December 2017
3. C-H bond oxidation by light, water and O2 in Symposium celebrating the Electron. Max Planck Institute, Hamburg, Germany, November 2017
5. Controlling Phe-Phe dipeptide aggregation by covalent attachment of an isomerizable photoswitch. Two day DAE meet of Biological Scientists, BARC, Trombay, March 2017
7. Fate of Excitons in Conjugated Organic Materials: Relaxation and Fission. Mumbai-Pune Semiconductor meeting at TIFR, Mumbai, February 2017

S Viola D’Mello
Member, Royal Society of Chemistry

September 4–8, 2017

S. J. Wategaonkar
Institute of Atomic and Molecular Sciences (IAMS), Taipei, Taiwan, September 7–8, 2017

Ankona Datta
1. Chemical Probes for Chelating and Sensing Redox-Active Metal Ions, Modern Trends in Inorganic Chemistry. MTIC-XVII, Pune, December 2017
2. Chemical Probes for Sensing Signaling Lipids and Metal Ions. Indo-German Meeting on ‘Elementary Reactions in Functional Materials: From Biophysics to Technological Applications’, Heidelberg, Germany, November 2017
3. Developing Synthetic Chemical Probes for Sensing Signaling Lípids and Metal Ions. Joint seminar in SYNMIKRO, Philipps-Universität Marburg, and Max Planck Institute for terrestrial Microbiology Marburg, Germany, November 2017
5. Designing Probes for In Vivo Molecular Tracking. 5th Symposium on Advanced Biological Inorganic Chemistry, Kolkata, January 2017

8. Tracking the Fate of Singlet Excitons in Conjugated Organic Materials: Relaxation and Fission. Chemistry Interfacing with Biology and Physics meeting (celebrating 10 years of IISER Kolkata), January 2017
7. Chemical Probes for Tracking Essential Biological Molecules and Ions. National Symposium on Recent Advances in Chemistry and Industry, IIEST, Kolkata, August 2017
8. Peptide-Based Fluorescent Probes for Imaging Signal Mediating Phospholipids, 6th Indian Peptide Symposium, HBCSE, Mumbai, February 2017
9. Fluorescent Sensors for Imaging Manganese. 5th Annual Meeting of Society for free radical research-India, BARC, Mumbai, January 2017

Deepa Khushhalani
1. CEAMCR-2018, 13th International Conference ISEAC, Mumbai, February 2018
2. 12th CRSI-RSC Symposium, Raipur, February 2018
3. International Conference on Nanomaterials for Energy Conversion and Storage Applications, Gandhinagar, January 2018
4. 4th DAE-BRNS National Workshop on Materials Chemistry, Mumbai, September 2017
5. Electron Microscopy, National Workshop, SIWS College, Mumbai, September 2017
7. Energy Transition Summit, Shell Tech. Centre, Bangalore, September 2017

A. S. R. Kati
1. Mechanical force as a tool to study protein unfolding and to rupture chemical bonds. Kaleidoscope: A Discussion Meeting in Chemistry, Goa, 6 July 2017
2. Biophysical studies on malaria parasite cell surface circumsporozoite protein (CSP). Recent Advances in Chemical Biology, The Meeting of Society of Biological Chemists (India), Mumbai Chapter, UM-DAE CEBS, Mumbai, 19 Aug 2017

Sudipta Maiti
1. Designing ligands for structureless proteins. CESSD 2018, IACS Kolkata, February 23, 2018
2. Imaging Neurons: Label-free. FIMB 2018, IISER Kolkata, January 19, 2018
5. How to find ligands for disordered proteins. Intrinsically Disordered Proteins, IISER Mohali, Dec. 9–12, 2017
6. How to find ligands for disordered proteins. International Conference on Systems, Synthetic and Chemical Biology, Bose Institute, Kolkata, Dec. 4–7, 2017
8. Finding ligands for intrinsically disordered proteins. NMR meets Biology III, Grossbothen, Germany, September 3, 2017
9. Amyloids in Membranes: Are They Porin-Like? Anti-Microbial Peptide meeting, University of Melbourne, Australia, April 19, 2017

Shyamalava Mazumdar
1. Role of substituents on the reactions of polyaromatics catalyzed by CYP175A1. 20th International Conference on Cytochrome P450: Biochemistry, Biophysics and Biotechnology, Dusseldorf Germany, 27–31 Aug 2017
2. Bio-nano Conjugation to Design Novel Redox Enzyme. Based Catalysts. Conference on advances in catalysis for energy and environment, TIFR, January 10–12, 2018
3. Doing Chemistry with the metal center. Proteins and nanomaterials: New directions of Bioinorganic Chemistry and nano-technology in designing novel nano-bio catalysts. Inaugural Key note lecture on the conference on Emerging trends in Chemical Sciences, Gauhati University, 29 January 2018

Vivek Palshetkar
1. Morphology Makes the Difference: Dendritic Fibrous Nano-Silica (DFNS) for Catalysis and CO2 Capture. University of Nevada, USA, 2 February 2018
2. Dendritic Fibrous Nanosilica (DFNS) for Catalysis and CO2 Capture-Conversion. VISTEC, 25 September 2017
4. Role of Nanomaterials Morphology in Catalysis and CO2 Capture. Workshop on Advanced Materials for Energy, Department of Materials Science, Indian Association for the Cultivation of Science, Jadavpur, Kolkata, 16 March 2018
7. Dendritic Fibrous Nanosilica (DFNS) for Catalysis and CO2 Capture. Chemistry Refresher Course to Teachers, Mumbai University, 3 November 2017
8. Dendritic Fibrous Nanosilica for Catalysis and CO2 Capture. ICAR-Central Institute for Research on Cotton Technology, 13 September 2017
9. Dendritic Fibrous Nanosilica for Catalysis and CO2 Capture. Prof. A. V. Karnik Endowment Lecture, 10. September 2017
11. Dendritic Fibrous Nanosilica (DFNS) for Catalysis and CO2 Capture. SASChem Satellite meeting of IUCr 2017 Congress, IISER Kolkata, 29–30 August 2017
12. Dendritic Fibrous Nanosilica (DFNS) for Catalysis and CO2 Capture. International Conference on Nanoscience and Nanotechnology, SRM University, Chennai, 9–11 August 2017

Ravindra Venkatramani
1. Optical Charge Transfer Transitions in Proteins Arising from Charged Amino Acids: New Label Free Spectroscopic Markers to Probe Protein Structure and Dynamics. Recent Advances in Molecular Simulations, IISc-Bangalore, February 8–11, 2018
3. Understanding the Function of Ubiquitin Family Proteins using Dynamics as a Molecular Descriptor. NMR meets Biology: Indo-German Workshop, Großbothen, Germany, September 4–8, 2017

6. Towards Quantitative Descriptions of Biomolecular Dynamics: Computational and Spectroscopic Descriptors. Centre for Cellular and Molecular Biology (CCMB), Hyderabad, June 15 2017

S. J. Wategaonkar
1. Thermochemistry of Weakly Bound Complexes. SDMC 2018, Dooars, February 15–18, 2018
5. Strength of Weak (Non-Covalent) Interactions. ICTS Colloquium, Bengaluru, October 16, 2017
6. C(2)H—O Interaction in Histidine Side-Chain. IAMS, Taipei, Taiwan, September 7, 2017
7. Nothing Improper about CH•••Y Hydrogen Bonds. Plenary lecture at the Sixth Asian Spectroscopy Conference, National Tsing Hua University, Taiwan, September 3–6, 2017

Viola Caroline D'mello

Conferences Organized by the Department

Biophysics Pashchim meeting
IISER Mohali, November 4, 2017

FCS 2017, National Workshop on Fluorescence and Raman Spectroscopy
IIT Guwahati, December 17–21, 2017

Conference on Advances in Catalysis for Energy and Environment (CACEE-2018)
TIFR, Mumbai, January 10–12, 2018

Non-DAE Research Projects

K. V. R. Chary
DST-DIIRSRE joint Research Project under Australia-India Strategic Joint Research Fund (AISRF)

P. K. Madhu
Novel nanocatalysts synthesis guided by DNP NMR. Indo-French IFCPAR/CEFIPRA project

Vivek Polshettiwar
Oxides

Magnetodielectric coupling anomalies in the Haldane spin-chain family $R_2$BaNiO$_5$

The compound, Tb$_2$BaNiO$_5$, has been known to order antiferromagnetically below ($T_N$) = 63 K. Our magnetic studies carried out on the polycrystals bring out that there is another magnetic transition at a lower temperature ($T_2$) = 25 K, with a pronounced magnetic-field induced metamagnetic and metaelectric behavior. Multiferroic features are found below $T_2$ only, and not at $T_N$ (unlike in some other heavy R members). The most intriguing observation is that the observed change of dielectric constant ($\Delta\varepsilon$) is intrinsic and largest (e.g., $\sim 18\%$ at 15 K) within this Haldane spin-chain family, $R_2$BaNiO$_5$. Taking into account the fact that this trend (that is, the largest value of $\Delta\varepsilon$ for Tb case) within this family correlates well with a similar trend in $T_N$ (with the values of $T_N$ being 55, 58, 53 and 32 K for Gd, Dy, Ho and Er cases), we believe that the explanation usually offered for this $T_N$ behavior in rare-earth systems is applicable for this $\Delta\varepsilon$ behavior as well. That is, single-ion anisotropy following crystal-field splitting is responsible for the extraordinary magnetodielectric (MDE) effect in this Tb case. To our knowledge, such an observation was not made in the past literature of multiferroics. [Sanjay Upadhyay, P. L. Paulose, and E.V. Sampathkumaran]

The compound, Eu$_2$BaNiO$_5$, has been known to exhibit a magnetic transition in the vicinity of 5 K from Eu and Ni, but we do not find any evidence for ferroelectricity above 2 K, in sharp contrast to the multiferroic behavior reported for other members of this Haldane spin-chain family. Instead, there is a pyrocurrent peak around 40 K, which is sensitive to the rate of change of temperature, thereby providing an evidence for thermally stimulated depolarization current. Additionally, this study brings out two more features: (i) There is a dielectric anomaly in the range 75–100 K, attributable to short-range magnetic correlations, similar to the situation encountered in another spin-chain system Ca$_3$Co$_2$O$_6$, and (ii) there is a sign crossover of MDE with varying magnetic field well below 8 K only, with relatively negligible values of MDE above 4 K, and this observation establishes the existence of a coupling between magnetic and electric dipoles at the onset of long-range magnetic order. [Sanjay Kumar Upadhyay, Kartik K. Iyer, and E.V. Sampathkumaran]

The compound, Sm$_2$BaNiO$_5$, which was known to order antiferromagnetically around 55 K, was investigated for its complex dielectric permittivity, magnetodielectric and pyrocurrent behavior as a function of temperature ($T$). We emphasize on the following findings: (i) There is a pyrocurrent peak near $T_N$, but it is shown not to arise from ferroelectricity, but possibly due to ‘thermally stimulated depolarization current’, unlike in many other members of this rare-earth series in which case ferroelectric features were reported at or above $T_N$; (ii) however, the pyrocurrent measured in the presence of a bias electric field (after cooling in zero electric field) as well as dielectric constant reveal a weak peak with increasing $T$ around 22 K – the temperature around which population of the exchange-split excited state of Kramers doublet has been known to occur. This finding suggests that this compound presents a novel situation in which multiferroicity is induced by an interplay between crystal-field effects and exchange interaction. No multiglass features could be observed down 2 K unlike in many other members of this family. [Sanjay Kumar Upadhyay, Kartik K. Iyer, and E. V. Sampathkumaran]
Thus, this systematic work on this family reveals a variety of magnetoelectric coupling anomalies within this family, offering many inputs for the advancement of the field of multiferroics.

**Complex nature of magnetic field-induced ferroelectricity in GdCrTiO$_3$**

Recently, the family RCrTiO$_3$ has started attracting some attention in the literature from the angle of magnetoelectric coupling. Our previous investigations on GdCrTiO$_3$, a heavy rare-earth member of this series, provided an evidence for a magnetic-field induced dielectric anomaly around 10 K, similar to the observations in NdCrTiO$_3$. However, no clear signature of long-range magnetic order was observed, neither in the temperature dependence of the magnetic susceptibility, nor in the heat capacity for GdCrTiO$_3$, unlike in NdCrTiO$_3$. This issue was addressed further by ESR and muon spin-rotation by our colleagues in Germany in collaboration with us addressed this issue further, providing evidence for a magnetic anomaly around 10 K, supporting our earlier conclusions. [Tathamay Basu, D. T. Adroja, F. Kolb, H. A. Krug von Nidda, A. Ruff, M. Hemmida, A. D. Hillier, M. Telling, E. V. Sampathkumaran, A. Loidland S. Krohns]  

**Novel magnetism of Li based transition metal oxides**

During last year, we stressed the need to discover new Li containing materials and to understand their physical properties. We reported novel magnetic behavior of Li$_3$Ni$_2$RuO$_6$ (monoclinic crystal structure, space group, C2/c) and Li$_3$Co$_2$RuO$_6$, and Li$_3$FeRuO$_6$, crystallizing in LiCoO$_2$-type structure (rhombohedral, $R \bar{3}m$ space group). We continued our efforts in studying Li-based oxides for their magnetic and magnetoelectric anomalies.

We find re-entrant cluster spin-glass behaviour in a Li-based polycrystalline, Li$_3$NiRuO$_3$, not paid much attention for its properties in the literature. This oxide undergoes ferrimagnetic ordering below 80 K and enters spin glass regime around 12 K. Though there is no well-defined feature in the complex dielectric permittivity in the magnetically ordered state in the absence of an external magnetic field, indicative of the absence of ferroelectricity, there is a distinct evidence for magnetodielectric coupling. Consistent with MDE coupling, the sign of MDE coupling also changes as the sample is cooled from ferrimagnetic state to spin-glass regime. There are pyroelectric anomalies in the vicinity of 30 – 70 K, presumably arising from thermally stimulated depolarization current. [Sanjay Kumar Upadhyay, Kartik K Iyer, S. Rayaprol, V. Siruguri, and E.V. Sampathkumaran].

In the case of Li$_3$Co$_2$RuO$_6$, though an initial report in the literature proposing onset of antiferromagnetism at 10 K, based on dc magnetic susceptibility measurements performed in a magnetic field of 1kOe, our extensive magnetic measurements confirm that there is no magnetic transition down to 1.8 K in this compound, despite a large value of paramagnetic Curie temperature. Therefore, possible spin-liquid behavior is not ruled out in this system. [Sanjay Kumar Upadhyay, Kartik K. Iyer, and E.V. Sampathkumaran].

Keeping current interests to identify materials with intrinsic magnetodielectric behaviour near room temperature and with novel pyroelectric current anomalies, we reported temperature and magnetic-field dependent behavior of complex dielectric permittivity and pyroelectric current for an oxide, Li$_3$Ni$_2$Mo$_3$O$_{12}$, containing magnetic ions with (distorted) honey-comb and chain arrangement and ordering magnetically below 8 K. The dielectric data reveal the existence of relaxor ferroelectricity behaviour in the range 160–240 K and there are corresponding Raman mode anomalies as well in this temperature range. Pyrocurrent behavior is also consistent with this interpretation, with the pyrocurrent peak-temperature interestingly correlating with the poling temperature. $^7$Li NMR offer an evidence for crystallographic disorder intrinsic to this compound and we therefore conclude that such a disorder is apparently responsible for the randomness of local electric field leading to relaxor ferroelectric property. Another observation of emphasis is that there is a notable decrease in the dielectric constant with the application of magnetic field to the tune of about -2.4% at 300 K, with the magnitude varying marginally with temperature. Small loss factor values validate the intrinsic behaviour of the magnetodielectric effect at room temperature. [Sanjay Kumar Upadhyay, Kartik K. Iyer, Smita Gohil, Shankar Ghosh, P. L. Paulose, and E. V. Sampathkumaran].
**Intermetallics**

Geometrically frustrated magnetic anomalies in $\text{R}_2\text{RuAl}_2$ ($\text{R} = \text{ Tb}, \text{Er}$), layered compounds with distorted kagome net

During last year, we initiated some work on polycrystals of intermetallic-based kagome lattices on the rare-earth family of the type $\text{R}_2\text{RuAl}_2$, the importance of which was reported in the report of the last year, presenting the results on $\text{R} = \text{Gd}$ and $\text{Dy}$ members. As a continuation of our efforts (on polycrystals) in this family, we studied the members $\text{R} = \text{Tb}$ and $\text{Er}$ by bulk experimental methods.

The main finding is that the polycrystals of Tb compound, known to order antiferromagnetically below ($T_N = $) 22 K, shows glassy characteristics at lower temperatures ($< $ 15 K), thus characterizing this compound as a re-entrant spin-glass. The data reveal that the glassy phase is quite complex and is of a cluster type. Since glassy behavior was not seen for the Gd analogue, this finding on the Tb compound emphasizes that this kagome family could provide an opportunity to explore the role of asphericity of the orbital responsible for magnetism in bringing out magnetic frustration. Additional findings reported here for this compound are: (i) The magnetic transition near 22 K is found to be hysteretic as revealed by temperature dependence of magnetic susceptibility and electrical resistivity ($\rho$) data; (ii) features attributable to an interesting magnetic phase co-existence phenomenon in the magnetoresistance in zero field, after cycling across metamagnetic transition fields, are observed. With respect to the Er compound, we do not find any evidence for long-range magnetic ordering down to 2 K, but this compound appears to be on the verge of magnetic order at 2 K. [Sanjay Kumar Upadhyay, Kartik K Iyer, and E.V. Sampathkumaran].

**Magnetic behavior of new compounds, $\text{Gd}_4\text{RuSn}_6$ and $\text{Tb}_2\text{RuSn}_6$**

We reported T-dependence of dc magnetization, electrical resistivity and heat-capacity of rare-earth compounds, $\text{Gd}_4\text{RuSn}_6$ and $\text{Tb}_2\text{RuSn}_6$, which are found to crystallize in the $\text{Yb}_3\text{CoSn}_6$-type orthorhombic structure (space group: Cmcm). The results establish that there is an onset of antiferromagnetic ordering near 19 and 25 K respectively. We find that there is another magnetic transition for both the cases around 14 and 17 K respectively. In the case of the Gd compound, the spin-scattering contribution to $\rho$ is found to increase below about 75 K as the material is cooled towards $T_N$, thereby resulting in a minimum in the plot of $\rho(T)$ unexpected for Gd based systems. There are sign reversals in the plot of isothermal entropy change versus T in the magnetically ordered state, indicating subtle changes in the spin-orientations with T. The results reveal that these compounds exhibit interesting transport properties. [Sanjay K Upadhyay, Kartik K Iyer, and E.V. Sampathkumaran].

**$\alpha$-Titanium – Revisit of the electrical resistivity on a single crystal**

Titanium metal has a widespread applications in a wide temperature range. Ti alloyed with Nb is used for making superconducting magnets at ambient temperatures, Ti and its alloys are used for biomedical applications. $\alpha$-Titanium crystallizes in hexagonal close packed structure with $a = 2.951 \, \text{Å}$ and $c = 4.684 \, \text{Å}$ with a $c/a$ ratio of 1.6. The electronic configuration of Ti ($[\text{Ar}]3d^24s^2$) indicates the presence of two bands at Fermi level. Therefore, the temperature dependence of electrical resistivity of $\alpha$-Ti is expected to be influenced by the crystal anisotropy, Fermi surface anisotropy, the multiple bands at the Fermi level and the anisotropy of the phonon dispersion. The temperature dependence of resistivity $\rho(T)$ of a polycrystalline sample and a single crystal sample (current along the [0001] direction) of $\alpha$-Titanium (Ti) at low temperatures was revisited to understand the electrical charge transport phenomena in this hexagonal close pack metal. We found that the $\rho(T)$ in single crystal Ti can be explained by considering the scattering of electrons due to electron-phonon, electron-electron, inter-band s-d and electron-impurity interactions, whereas the $\rho(T)$ of polycrystalline Ti could not be explained by these interactions alone. We observed that the effects of the anisotropy of the hexagonal structure on the electronic band structure and the phonon dispersion need to be taken into account to explain $\rho(T)$ of polycrystalline Ti. Two Debye temperatures corresponding to two different directions for the electron-phonon interactions and inter-band s-d scattering are needed to account the observed $\rho(T)$ in polycrystalline Ti. [S. K. Dhar, A. Thamizhavel, Rajib Mondal; L. S. Sharath Chandra and S. B. Roy (RRCAT)]
Superconductivity and CDW in LaPt$_3$Si$_2$ single crystal

Among the 3D charge density wave (CDW) materials the members of Pt based rare earth intermetallic seriesRPT$_2$X$_2$ (R = rare earth metal, X = Si, As) are of keen interest as CDW instability appears along with superconducting transition and it is interesting to see how these two phases interact with each other at low temperature. Among these compounds, LaPt$_3$Si$_2$ crystallizes in non-centrosymmetric CaBa$_2$Ge$_2$ type tetragonal structure. We have grown the single crystal of LaPt$_3$Si$_2$ and studied its anisotropic physical properties. The increase in resistivity and decrease in susceptibility below 85 K along both the principal crystallographic axis confirmed the partial gap opening at the Fermi surface due to CDW transition. The superconducting transition was observed at around 1.79 K. Bulk nature of the superconductivity was confirmed through specific heat which displayed a sharp anomaly associated with the superconducting transition. The hysteresis between cooling and heating data of the temperature dependent resistivity around $T_{CDW}$ confirmed the first order nature of the transition. The reduced value of jump in specific heat at superconducting transition confirmed the weak electron phonon coupling in our system. [S. K. Dhar, A. Thamizhavel, Ritu Gupta (IIT Kanpur), K. P. Rajeev (IIT Kanpur) and Zakir Hossain (IIT Kanpur)]

Non-centrosymmetric superconductor Re$_3$Hf

In continuation to our studies on Re$_6$Zr, we have investigated the superconducting properties of Re$_3$Hf. A single phase polycrystalline sample of Re$_3$Hf was prepared by arc melting technique, which crystallizes the cubic, non-centrosymmetric α-Mn type crystal structure with lattice parameter $a = 9.6850(3)$ Å. Physical property measurements revealed that Re$_3$Hf is a weakly correlated, type-II superconductor with $T_c \approx 5.96$ K. Above transition temperature $T_c$, resistivity measurement showed the poor metallic behavior whereas magnetization measurement showed weak paramagnetism. The computed value of the upper critical field $H_{c2}(0) (\approx 12.2$ T) is close to the Pauli limiting field, hence further investigations need to be done to explore the possible mixture of singlet and triplet pairing states. It is interesting to note that the superconducting properties are almost similar for both Re$_6$Zr and Re$_3$Hf in spite of the fact that Re$_3$Hf has a much stronger spin-orbital coupling strength compared to Re$_6$Zr. Our results suggest that along with spin-orbital coupling strength some other mechanism/phenomena is playing a role in determining the strength of spin-singlet and spin-triplet pairing channel. In order to fully understand the role of spin-orbital coupling, further experimental work on high-quality single crystals is required. [A. Thamizhavel and R. P. Singh (IISER, Bhopal)]

Stripe order in Ba$_2$Ni(PO$_4$)$_2$

We studied the crystal structure and magnetic behavior of spin $S = 1$ compound Ba$_2$Ni(PO$_4$)$_2$ with a honeycomb like topology of the spin lattice. From the magnetic measurements we found that there are two successive magnetic transitions at $T_{N1} = 5$ K and $T_{N2} = 4.6$ K. Additionally, we found a broad peak at around 8 K, which was a sign of short range magnetic order above $T_{N1}$. For temperatures below $T_{N1}$ field induced transitions around 4 and 10 T were observed. Neutron diffraction measurements established stripe antiferromagnetic order below $T_{N2}$ with an ordered moment of 1.75 μB/Ni$^{2+}$ at 1.5 K. Density functional band structure calculations reveal the leading interactions $J_3 = 3.5$ K running perpendicular to the honeycomb planes, and weaker interactions $J_1 = 0.5$ K and $J_4 = 1.8$ K within the honeycomb planes whereas the stripe order is stabilized by the diagonal interlayer interactions $J_2 = 1.3$ K that frustrates $J_1$. This is in contrast to the usually expected scenarios where the competing second and third nearest neighbour interactions on the honeycomb lattice stability the stripe order. The Ni$^{2+}$ ions feature a sizeable easy-plane anisotropy but the position of the easy plane changes from one atom to another, thus amplifying the magnetic frustration. [Arvind Yogi, Arvind Maurya, Ruta Kulkarni, A. Thamizhavel, A. K. Bera (BARC), S. M. Yusuf (BARC), A. Hoser (HZB Berlin), A. A. Tsirlin (University of Augsburg, Germany)]

High-pressure studies on the properties of FeGa$_3$

FeGa$_3$ crystallizes in the tetragonal crystal structure with the space group $P4_2/mmm$. Single crystals of FeGa$_3$ were grown from a gallium rich melt. High pressure x-ray diffraction (XRD) on FeGa$_3$ was performed from ambient pressure to 33 GPa. The high pressure XRD revealed that the system remains in tetragonal crystal structure below 20 GPa. For pressures greater than 20 GPa, the intensities of the diffraction peaks decreased drastically and eventually beyond 26 GPa a broad peak was observed something
similar to amorphous sample. However, upon releasing the pressure we found that the material transform back to crystalline nature with reduced intensity and not so sharp peaks. High pressure electrical resistivity measurement up to a pressure of 9 GPa was performed on the single crystalline FeGa. The electrical resistivity was found to decrease continuously from 1 to 9 GPa with a small discontinuity around 4 GPa. [A. Thamizhavel; D. Mondal, V. Srirhari, C. Kamal, H. Poswal, Alka B. Garg, Soma Banik, A. Chakrabarti, S. M. Sharma and Tapas Ganguli (RRCAT)]

**Giant Rashba effect in PrGe single crystal**

We observed giant Rashba spin-orbit splitting on the PrGe (010) surface in the paramagnetic phase with Rashba coefficient $\alpha_R = 5 \text{eV}a$. We found that $\alpha_R$ can be tuned in this system as a function of temperature at different magnetic phases. Rashba type spin polarized surface states originates due to the strong hybridization between the Pr$f$ states with the conduction electrons. Significant changes observed in the spin polarized surface states across the magnetic transitions which were attributed to the competition between Dzyaloshinsky-Moriya (DM) interaction and exchange interaction present in this system. Supporting evidences of DM interaction were obtained from anisotropic magnetoresistance with respect to field direction and first-order type hysteresis in the temperature dependence of X-ray diffraction measurements. A giant negative magnetoresistance of 43% in the antiferromagnetic phase and tunable Rashba parameter with temperature makes this material a suitable candidate for application in the antiferromagnetic spintronic devices. [P. K. Das, A. Thamizhavel, A. Bendounan, I. Vobornik, A. Arya, N. Beaulieu, Jun Fuji, P. U. Sastry, A. K. Sinha, D. M. Phase and S. K. Deb]

**Single crystal growth and anisotropic magnetic properties of HoAl$_2$Ge$_2$**

Following our earlier work on EuAl$_2$Si, we have explored the magnetic behaviour of iso-structural HoAl$_2$Ge$_2$ in which the Ho ions form triangular nets in the $ab$-plane. The compound orders antiferromagnetically at $T_N \sim 6.5 \text{K}$ with apparently no signature of frustration. A prominent Schottky anomaly with a broad peak centred around 25 K suggests a relatively low crystal electric field splitting. The electrical resistivity reveals the occurrence of a superzone gap below $T_c$. [Md. Matin, Rajib Mondal, A. Thamizhavel, S. K. Dhar; A. Provino and P. Manfrinetti (University of Genova, Italy)]

**Ultra large magnetoresistance and possible topological protection in MoSi$_2$**

Recently ultra large magnetoresistivity (XMR) has been reported in a number of semimetals such as WTe$_2$, NbP, LaSb, NbAs, TaP, TaAs, MoTe$_2$ and MoP$_2$. While LaSb exhibits XMR due to perfect electron-hole compensation, topological protection provided by the band structure has been invoked to account for XMR in the other materials. A previous study on MoSi$_2$ had reported a MR of $\sim 10^6$ % at 2 K and 7.5 T and explained it to arise from electron-hole compensation. We have observed an XMR approaching almost $10^7$ % at 2 K and 14 T field without appreciable saturation in a single crystal of MoSi$_2$ with a residual resistivity ratio of $\sim 3926$ for $J // a$. Hall resistivity data reveal an uncompensated nature of MoSi$_2$. Magnetotransport and quantum oscillations associated with dHvA and SdH effects suggest that strong Zeeman effect causes a magnetic field-induced modulation of the Fermi pockets and drives the system towards perfect electron-hole compensation in the high-field regime. The non-saturating XMR of MoSi$_2$ thus arises from field driven electron-hole compensation and its magnitude is decided by the ultra large value of the carrier mobility. Intrinsic ultra large carrier mobility, strong suppression of backward scattering of the charge carriers, non-trivial Berry phase in dHvA quantum oscillations and a paramagnetic singularity in $\chi(B)$ near zero field due to spin texture indicate possible topological character of MoSi$_2$. The latter aspect needs to be studied in greater detail for confirmation. [M. Matin, R. Monda, N. Barman, A. Thamizhavel, S. K. Dhar]

**Semiconductors**

**Optical spectroscopy of semiconductors**

We have continued to work on transition metal dichalcogenide (TMDC) semiconductors. Excitons and trions in mono/few layers of these materials show exotic properties such as non-hydrogenic spectrum, large binding energy $E_b$, strongly anisotropic wavefunction spread, sensitivity to circular polarization
of light arising from spin-valley coupling, presence of optically dark excitons and the possibility of interlayer excitons. Are some of these properties also present in bulk? We have studied excitons in bulk WS₂ around its direct bandgap using optical spectroscopy. Reflectance and absorption measurements at low temperature show one dominant spectral feature at 2.02eV attributed to the A exciton transition at the K-point of the Brillouin zone (BZ). In contrast, a laser-modulated photoreflectance (PR) spectrum, revealed in addition to A, a stronger feature A* about 62meV above A. Reports on MoS₂ had suggested that a similar feature there was due to a new excitonic transition at the H-point of the BZ. Or was this the next excited state A(n=2) transition of A? If the latter was true then strength of A* should be A/8. To probe further we performed lateral electroreflectance (LER) spectroscopy by fabricating aluminum contacts through photolithography. The relative intensity of the two features in LER appeared to change significantly with A* now much weaker in strength than A. These experimental results were analyzed by comparison with many-body perturbation theory calculations, including the solutions of the Bethe-Salpeter equation. It was inferred that excitonic transitions at the H-point is not possible and that A* was indeed the first excited state A(n=2) though it does not follow the hydrogenic model in terms of energy position and strength. The anomalous behaviour of A* in PR/LER is explained by the wavefunction spread of A(n=2) along the c-axis, the direction of weak van der Waals bonding, which makes it more susceptible to perturbations including its orientation. The calculations suggest that the A exciton in the ground state has two-dimensional nature with a large Eb. From a temperature dependent reflectance study we obtained Eb= 90+/-.20meV, in fair agreement with calculations.

In a collaborative study with J. Wu’s group at Univ. of California, Berkely it was shown that heavy substitutional doping with 0.1% to 1% Nb can alter the crystal structure of MoS₂ from 2H to 3R form. Our contribution was to show using low temperature microreflectance spectroscopy that the electronic structure has indeed changed from 2H to what is expected in 3R form. We have also been studying the origins of Stokes shifts of emission from monolayer MoS₂ and trying to understand it origins using different techniques that include micro-Raman and time resolved luminescence measurements. Other studies on monolayer MoSe₂ have focused on trying to understand the origins of Fano resonance like character in its absorption spectrum. All studies were on small flakes of TMDCs for which we used our home built setups for spectroscopy with micrometer spatial resolution at cryogenic temperatures. [Vishwas Jindal, Sumi Bhuyan, Dipankar Jana, Vasam Sugunakar and Sandip Ghosh]

**Unusual electronic state properties of a single crystal of Ag₄SSe at low temperatures**

The superionic electrical conductor Ag₄SSe is reported to undergo an unusual first-order structural phase transition at ~260 K with concomitant anomalous electronic properties. Single-crystal X-ray diffraction reveals that the crystal undergoes a structural transition from monoclinic α-Ag₄SSe to an orthorhombic crystal structure below 260 K. The new low-temperature phase is denoted as δ-Ag₄SSe. All measured physical properties exhibit hysteresis at the α-δ transition, suggesting a first-order phase transition. The diamagnetic magnetic susceptibility is of larger magnitude in the δ than α phases. Such a diamagnetic drop cannot be ascribed to the formation of a charge density wave (CDW), since the electrical resistivity shows the metallic behavior off δ-Ag₄SSe. A diamagnetic susceptibility of larger magnitude is usually related to a lower density of states at the Fermi level, which leads to a decrease in the Pauli paramagnetic susceptibility. Such a decrease in the density of states often results in an increase in resistivity, unless the mobility of the charge carriers changes significantly. Hence, we believe that in Ag₄SSe, the α-δ structural transition causes an unusual Fermi surface reconstruction, which in turn leads to a strange metallic behavior. Band structure calculations substantiate such a claim. In addition, we also observe the spontaneous voltage generation (SVG) at the phase transition, which has previously been observed only in a few magnetic materials. [S. Ramakrishnan in collaboration with Professor Sander van Smaalen, University of Bayreuth, Germany]

**Novel non-Fermi liquid state in site disordered Ni₁δV₂₋δSe₁ crystal**

We report the temperature dependent structural, electronic and magnetic properties on Ni₁δV₂₋δSe₁ single crystal. The symmetry of the compound Ni₁δV₂₋δSe₁ at room temperature is described by the space group I2/m. Single crystal X-ray diffraction data were collected at 100 K shows no structural transition. A better structural model was presented using the
anharmonic anisotropic displacement parameters. The structural data show no evidence of any charge density wave transition at 100 K. The resistivity (\(\rho(T)\)) shows the metallic behavior with a broad anomaly between 150-200 K. The magnetic susceptibility displays a paramagnetic behavior and isothermal magnetization data reveal a weak magnetic transition below 15 K. The heat capacity data show a small anomaly around 140 K, which is consistent with those anomalies exhibited by magnetic susceptibility and resistivity measurements. In addition, the temperature dependence of the resistivity is quite anomalous. Between 15 K to 150 K, resistivity shows \(T^{3/2}\) dependence and below 15 K it exhibits a \(T^2\) dependence down to 1.6 K. We believe the existence of strong antiferromagnetic fluctuations up to 150 K could be responsible for \(T^{3/2}\) dependence exhibited by resistivity data and the magnetic ordering below 15 K leads to the Fermi liquid behavior as shown by the \(T^2\) dependence of the resistivity. The analysis of the low temperature heat capacity data shows the existence of such magnetic fluctuations and an enhanced value of the Sommerfeld coefficient (\(\gamma\)) was estimated to be 104 mJ/mol K\(^2\) suggesting strong electron-electron correlations in this system. We believe that the system exhibits a Non-Fermi liquid to a Fermi liquid behavior under ambient pressure. The presence of weak magnetic ordering (borderline magnetism) and quenched disorder could be the cause of the above mentioned phenomenon. [S. Ramakrishnan in collaboration with Prof. Sander van Smaalen at the University of Bayreuth, Germany]

**Unusual ground states in \(\text{R}_3\text{Ir}_2\text{Si}_9\) (\(\text{R} = \text{rare earth; T = Rh, Ir};\) and \(\text{X} = \text{Si, Ge, Sn})\): A review**

The study of multiple phase transitions is one of the frontier areas of condensed matter physics. Large numbers of investigations have been devoted to the development of understanding local moment magnetism, superconductivity, giant magnetoresistance and charge density wave (CDW) ordering in both inorganic and organic compounds. It is now known that ternary rare earth silicides, germanides and stannides, which form in a rich variety of crystal structures, exhibit multiple phase transitions. Rare earth compounds of the type \(\text{R}_3\text{Ir}_2\text{Si}_9\) (\(\text{R} = \text{rare earth; T = Rh, Ir};\) and \(\text{X} = \text{Si, Ge, Sn})\) display a variety of phase transitions towards exotic states, including charge density waves (CDW), local moment magnetism, antiferromagnetism in the heavy fermion state, superconductivity and giant positive magnetoresistance. They support strongly correlated electron systems. In particular, \(\text{R}_3\text{Ir}_2\text{Si}_9\) (\(\text{R} = \text{Dy–Lu})\) exhibit strong coupling CDWs with high transition temperatures, and superconductivity or magnetic ordering at lower temperatures. \(\text{R}_3\text{Ir}_2\text{Ge}_9\) (\(\text{R} = \text{Gd–Tm; T = Co, Rh, Ir})\) show multiple magnetic transitions with large magnetoresistance below the magnetic transitions. Finally, the light rare earth series \(\text{R}_3\text{Ta}_2\text{Sn}_{10}\) (\(\text{R} = \text{Ce, Pr, Nd; T = Rh, Ir})\) display heavy fermion behaviour (for Ce and Pr) or possess giant positive magnetoresistance (for Nd) at low temperatures. This review provides a comprehensive overview of compounds, crystal structures and phase transitions. This is followed by an in-depth discussion of the mechanisms of the phase transitions and the properties of the ordered states. Unlike theories which exist for strong coupling SCS, theoretical studies in strong coupling CDW are rare. We believe \(\text{R}_3\text{Ir}_2\text{Si}_9\) offers a convenient paradigm for theoretical understanding of CDW and its coexistence with magnetism or superconductivity. [S. Ramakrishnan in collaboration with Prof. Sander van Smaalen at the University of Bayreuth, Germany]

**Synthesis, magnetic and electrical properties of \(\text{R}_3\text{AlC}_x\) (\(\text{R} = \text{Ce, Pr and Nd})\)**

Addition of small atoms like \(Z = \text{C, N and O to parent R}_3\text{Al}\) is found to stabilize \(\text{R}_3\text{AlZ}\) series of compounds in the cubic perovskite structure (Pm-3m) for all R atoms. This fact has been known since 1960’s. The structure and lattice parameters of \(\text{La}_3\text{AlC}\) have been reported earlier. There are only a few studies carried out on \(\text{R}_3\text{AlC}\) (\(\text{R} = \text{Ce, Pr})\). In order to understand the role of Carbon, \(\text{R}_3\text{AlC}_x\) (\(\text{R} = \text{Ce, Pr and Nd; x = 0–1})\) series has been synthesized by arc melting. Rietveld analysis of x-ray powder diffraction reveals cubic (Pm-3m) structure. A Kondo temperature \(T_K \sim 1\) K is estimated for \(\text{Ce}_3\text{AlC}_{0.65}\) from the susceptibility and resistivity data. Magnetic susceptibility measurements indicate antiferromagnetic (AFM) order for \(\text{R} = \text{Pr (x = 0.8 and 1)}\) and \(\text{Nd (x = 0.6, 0.8 and 1})\) and ferromagnetic (FM) for \(\text{Nd}_3\text{Al}\). Metamagnetic behaviour in the magnetization curve indicates complex magnetic structure. Band structure calculations indicate growth of a pseudo-gap in the density of states (DOS) from \(\text{Ce}_3\text{AlC}\) to \(\text{Pr}_3\text{AlC}\) to \(\text{Nd}_3\text{AlC}\). The DOS calculations predict a metallic behaviour which is consistent with the resistivity measurements. [S. Ramakrishnan in collaboration with S.S. Ghule and C.S. Garde at Vishwakarma Institute of Information Technology,
Growth of nanoneedles of InAs on Si(111) substrates

Nanoneedles (NNs) – tapered nanowires with a relatively thick base and sharp tip – may be useful for studying mesoscopic phenomena and also for the integration of III/V compound semiconductors on silicon. We optimized the growth of InAs NNs on Si(111) in an MOVPE reactor via the gold-catalyst mediated vapour-liquid-solid technique. Low temperature and high V/III ratios favour the growth of thin nanowires. However, at 420 °C temperature with V/III ratio 50, uniform InAs NNs are obtained with hexagonal cross section and base and tip diameters 800 nm and 10 nm respectively and length of ~10 μm. The growth rate is ~1 μm/min. The NNs were characterized by electron microscopy, GIXRD, and Raman measurements. TEM images confirmed that the NNs are free of stacking faults, and GIXRD scans confirm the wurtzite crystal phase of the NNs. Raman mapping and polarization dependent Raman measurements were used to probe the vibrational modes of these NNs. [Mahesh Gokhale, Nilesh Kulkarni, R. D. Bapat, J. Parmar and Arnab Bhattacharya]

Optical float zone growth of single-crystal β-Ga$_2$O$_3$

Gallium oxide (Ga$_2$O$_3$) is an interesting wide bandgap transparent semiconductor for high-frequency devices. We have been optimizing the synthesis of single-crystal β-Ga$_2$O$_3$ using the optical floating zone technique. Over the past year good progress in obtaining large crack-free crystals was made, and a study of the effect of different gas ambient on the crystal quality was carried out. Thin slices from these crystals have been cleaved for use as substrates for the growth of GaN epilayers by MOVPE and optimization of the growth of GaN on Ga$_2$O$_3$ being carried out. [Emroj Hossain, A. A. Rahman, Rajib Mondal, Ruta Kulkarni, A. Thamizhavel, and Arnab Bhattacharya]

ICPRIE etching of β-Ga$_2$O$_3$

In parallel to the growth of bulk gallium oxide, we have worked on inductively-coupled plasma reactive ion etching (ICP-RIE) of β-Ga$_2$O$_3$ to develop techniques for patterning this material. Various plasma chemistries using SF$_6$/Ar, CHF$_3$/Ar, O$_2$/Ar, BCl$_3$/Ar, and Cl$_2$/Ar were studied, however, appreciable etchers were obtained only with chlorine and borontrichloride based plasmas. A high etch rate of 144 nm/min with a smooth surface morphology was obtained in BCl$_3$/Ar plasmas, compared to 19 nm/min in Cl$_2$/Arplasmas. The etching behavior of Ga$_2$O$_3$ shows more similarity to that of Al$_2$O$_3$ than to that of GaN. [A. P. Shah and Arnab Bhattacharya]

Characterization of anisotropic optical properties of thin and bulk-like ReSe$_2$

The rhenium-based layered dichalcogenide ReSe$_2$ crystallizes in a distorted triclinic structure which results in unique, anisotropic optical properties due to the reduced symmetry. We had earlier reported the synthesis of high-quality single crystals of ReSe$_2$ using a modified Bridgman method. These crystals were used to study polarization-resolved optical transmission and photoluminescence spectroscopy of excitons in 1T- ReSe$_2$ (collaborative work with Univ. of Münster). The excitons are strongly polarized with dipole vectors along different crystal directions, which persist from the bulk down to monolayer thickness. The excitons have high binding energies of 860 meV for the monolayer and 120 meV for bulk and are strongly confined within a single layer even for the bulk crystal. [Bhakti Parekh and Arnab Bhattacharya, in collaboration with A. Arora and Bratschisch research group, University of Münster]

Synthesis and characterization of WS$_2$ nanotubes by thermally-assisted sulfurization

While 2D layers of WS$_2$ have been extensively studied, there are very few investigations of WS$_2$ nanotubes. We developed a simple process for the synthesis of WS$_2$ nanotubes via the sulfurization of tungsten films under appropriate conditions and elucidated their formation mechanism. Electron-beam evaporated thin films of tungsten were sulfurized under flowing N$_2$ gas at 950-1000 °C temperature at atmospheric pressure to obtain WS$_2$ nanotubes. Using high-resolution scanning and transmission electron microscopy studies we showed that 2D WS$_2$ flakes curl up and wrap around themselves to form nanotubes. Micro-photoluminescence and micro-transmission studies were carried out to determine the optical properties of WS$_2$ nanotubes. [Emroj Hossain, Amit P. Shah, B. A. Chalke, R. D. Bapat, Jayesh B. Parmar and Arnab Bhattacharya, in collaboration with A. Arora and R. Bratschisch, University of Münster]
On the geometric phenomenology of dry friction

We produced a geometric framework to deal with mechanical systems which have unilateral and are subject to damping/friction, which cannot be treated within usual classical mechanics. We have illustrated the utility of this framework in various experimental realizations. [Shankar Ghosh, A. P. Merin, Nitin Nitsure]

Landau Level Diagram and the Continuous Rotational Symmetry Breaking in Trilayer Graphene

The sequence of the zeroth Landau levels (LLs) between filling factors ν = 6 to 6 in ABA-stacked trilayer graphene (TLG) is unknown because it depends sensitively on the nonuniform charge distribution on the three layers of ABA-stacked TLG. Using the sensitivity of quantum Hall data on the electric field and magnetic field, in an ultraclean ABA-stacked TLG sample, we quantitatively estimate the nonuniformity of the electric field and determine the sequence of the zeroth LLs. We also observe anticrossings between some LLs differing by 3 in LL index, which result from the breaking of the continuous rotational to C3 symmetry by the trigonal warping. [Mandar Deshmukh in Collaborators: Biswajit Datta (TIFR), Hitesh Agarwal (TIFR), Abhishek Samanta (TIFR), Amulya Ratnakar (TIFR), Kenji Watanabe (NIMS Japan), Takashi Taniguchi (NIMS Japan), Rajdeep Sensarma (TIFR)].

Tension mediated nonlinear coupling between orthogonal mechanical modes of nanowire resonators

We study the nonlinear coupling between orthogonal flexural modes of doubly clamped InAs nanowire resonators. The two orthogonal modes are formed by the symmetry breaking and lifting of degeneracy of the fundamental mode. The presence of a Duffing nonlinearity emerges when a mode is driven to large amplitudes. In this regime the modes are coupled due to the tension induced from the large amplitude of oscillations and is reflected in the hysteretic response of the mode that is not strongly driven. We study the driven-driven response of the mechanical modes to elucidate the role of nonlinear mode coupling in such mechanical resonators. The dynamics of the coupled modes studied here could prove useful in technological applications such as nanowire based vectorial force sensing. [Mandar Deshmukh in Collaborators: John Mathew (TIFR), Anand Bhushan (NIT, Patna)]

Studies on p-type frustrated magnetic system: CuFeO₂

Continuing our studies on delafossite family of compounds, generally known for its large unit cell and layered structure, CuFeO₂ a frustrated antiferromagnetic system has been investigated with Cr substitution. In CuCrO₂ the spins are align 120° to each other and form Heisenberg triangular lattice, whereas in CuFeO₂ spins are aligned antiparallel to each other and form Ising type triangular lattice. The temperature and field dependence of magnetization of CuCr₁ₓFeₓO₂ (0 ≤ x ≤ 1) series shows that the magnetic ground state of CuFeO₂ and CuCrO₂ (two end compounds) is antiferromagnetic in nature, however the intermediate compositions show significant changes in magnetic state. The Fe-rich compositions show presence of competing ferromagnetic and antiferromagnetic exchange interactions. The high temperature magnetization data for Fe-rich compounds exhibit a sharp para- to ferro-magnetic transition in the range 650 K - 750 K. Besides, magnetic studies, thermal conductivity measurements have also been carried out, and the study shows that the thermal conductivity decreases with Fe concentration. The results are being analysed for publication. [A.K. Nigam in collaboration with Preeti Bhobe and her group at IIT Indore]

Studies on Heusler alloys (Ga₂MnCo and Fe₂TiSn)

The interest in magnetic Heusler alloys continues unabated due to their technological applications that lead to the study of magnetotransport, magnetelastic and magnetocaloric properties, along with others. Apart from being technologically important; they are also interesting for investigating the nature of magnetic correlations in diverse magnetically ordered states like antiferro-magnetism, ferrimagnetism, and compensated ferrimagnetism to localized-itinerant ferromagnetism including a complex spin glass state.

The full Heusler alloys usually have the chemical formula X₂YZ, where X and Y are transition metals, and Z is main group element belonging to p block. Unlike such a standard Heusler form, the Ga₂MnCo composition has an 9th element in excess with two parts of Ga to one part each of Mn and Co, reversing the general chemical formula to ZXY, yet maintaining the
of magnetic in nature, following the Slater – Pauling rule. Also its electronic structure suggests it to be a semimetal with a small pseudo gap at fermi level. However, the ground state magnetic and transport properties of the compound are affected due to presence of strong antisite disorder between Fe and Ti. Theoretically, it has been predicted to have zero spin polarization, but it is possible to induce high spin polarization in the system with proper substitution at $Ti$ or $Sn$ site. A study has been carried out on $Sn$-substituted $Fe_xTiSn_{1-x}Sb_x$ alloys. The substitution of $Sb$ at $Sn$ site reduces the anti-site disorder as found from X-ray diffraction measurements. The electrical resistivity measurements indicate that for $x \geq 0.25$, the system changes from metallic to semiconducting behaviour. At low temperature, the carrier transport takes place via Mott’s variable range hopping (VRH) mechanism. A systematic increase in anomalous Hall effect (AHE) is observed with increasing $Sb$ substitution, which could be attributed to side jump or Berry phase curvature effect. The results of the above study have been published. [A.K. Nigam in collaboration with Tamalika Samanta, Sayan Chaudhuri and Preeti Bhobe at IIT Indore]

Study of Weak Ferromagnetism in Antiferromagnets

The phenomenon of weak ferromagnetism (WFM) in certain antiferromagnets (AFMs), including the classic case of $a$-$Fe_2O_3$, is associated with the experimental observation of a ferromagnetic like spontaneous moment, and has been explained as due to Dzyaloshinskii-Moriya interaction (DMI). Some of the WFM have been found to show piezomagnetism (PzM) when subjected to stress. In magnetic remanence ($\rho$) measurements, an unusually slow magnetic relaxation was observed in some of the WFM/PzM compounds. In order to further understand the magnetization relaxation dynamics in WFM, a detailed study of magnetic remanence ($\rho$) has been carried out in $a$-$Fe_2O_3$, $MnCO_3$ and $FeCO_3$ as a function of time and temperature, with samples over length scales from nano to bulk. The results show ultraslow magnetization dynamics in association with a robust magnetization pinning with unusual magnetic field dependence. The data suggests that the observed quasi-static remanence and its unique magnetic field dependence appear to be a footprint of WFM/PZM systems. [A.K. Nigam in collaboration with Ashna Bajpai and her group at IISER Pune]

Studies on Magnetic Antiperovskite

Continuing our work on magnetic antiperovskite, an attempt has been made to understand the role of tin and carbon in defining the magnetic state of $Mn_xSnCo$. A set of off-stoichiometric samples, $Mn_xSnCo_{1-x}$ and $Mn_xSn_xC$, were prepared to study the magnetic behavior through measurement of magnetization as a function of temperature, time and field. The results show a complex magnetic ground state with coexistence of ferro-magnetic (FM) and antiferro-magnetic (AFM) orders. Both, the $Sn$ as well as $C$ deficient compounds has distorted $Mn_xC$ octahedra that affect the dynamics between ferro- and antiferro – magnetic interactions. The Carbon deficiency causes a tensile strain on the $Mn_xC$ octahedra that strengthens the ferromagnetic interactions. On the other hand, Sn deficiency reduces the strain on $Mn_xC$ octahedral thereby resulting in a wider distribution of $Mn$ – $Mn$ bond distances, which strengthens both FM and AFM interactions. The above study thus suggests that both the Sn and C play the role of confining Mn atoms that leads to formation of distorted octahedra, which in turn give rise to a complex magnetic state in $Mn_xSnC$. [Elaine Dias and A.K. Nigam in collaboration with K.R. Priolkar and his group at Goa University, Goa under a joint BRNS project]

NMR studies on $Li_2Ni_{12}Mo_3O_{12}$, a compound with distorted honeycomb and spin-chains

$Li_2Ni_{12}Mo_3O_{12}$ is a compound containing magnetic ions with (distorted) honeycomb and chain arrangement and ordering magnetically below 8 K. The dielectric data reveal the existence of relaxor ferroelectricity
behaviour in the range 160 K - 240 K. We have carried out a detailed $^7$Li NMR measurements. A single Gaussian line was obtained at 293 K along with asymmetric quadrupole satellites. The quadrupolar coupling constant was estimated to be about 92 kHz at 290 K. The full width at half maximum ($\Delta$W) of the spectral line is found to be 22 kHz at 290 K. The Knight shift is found to be negligible down to 20 K due to weak coupling with the neighbouring nuclei. However, $\Delta$W is found to vary drastically with temperature and has a close resemblance to the variation of magnetic susceptibility. This indicates that $^7$Li NMR line-width and macroscopic magnetization have a common origin. Notably, below 20 K, there is a marked asymmetry in the spectra with respect to Gaussian line attributable to resonances with different widths from different Li sites (experiencing different hyperfine interactions depending on local magnetic environment, as the magnetically ordered regime is approached). In the absence of crystallographic disorder, there is only one site for Li and therefore this asymmetry supports the presence of anti-site Li ions in this compound. The magnetic Ni ion has two sites forming distorted honeycomb lattice and linear chains with different types of magnetic interactions as revealed by neutron diffraction and some fraction of Li occupies both these sites. The spectra well below 8 K is broadened considerably due to the transferred hyperfine field, signifying the onset of long range magnetic order. Spin-lattice relaxation time ($T_1$) behavior also is consistent with multiple Li sites. At least two distinct components, one with a $T_1$ of 10 ms and another with a $T_1$ of 3.5 ms, could be resolved at 290 K. As the temperature is decreased both the components remain distinct, and the magnitude of $T_1$ increases monotonously to 16.3 ms and 6.3 ms at 24 K. The ratio of these two components remains at about 75:25 throughout the temperature range of measurement. NMR thus provides evidence for crystallographic disorder, possibly the source of nanopolar behavior. [P.L. Paulose, Sanjay K. Upadhyay, Kartik K. Iyer, and E.V. Sampathkumaran]

**Long range magnetic order in a Kagome system, Li$_3$Cr$_3$P$_2$O$_{29}$**

We have been working on a family of Kagome materials with the intention of stabilizing quantum spin-liquid state. A kagomé lattice, a network of corner sharing triangles in two spatial dimensions (2D), is considered to be the most frustrated topology in 2D and displays varieties of ground states depending upon the value of spin quantum number, types of interactions and the anisotropies present. Kagome materials with $S=3/2$ have not been explored like $S=1/2$ to understand the spin dynamics. We have synthesized Li$_3$Cr$_3$P$_2$O$_{29}$ as a disorder free magnetically ordered 2D (Cr$^{3+}$ $S=3/2$) material with kagomé lattice. It crystallizes in a hexagonal unit cell and CrO$_6$ octahedra form 2D Kagomé layers in ab-plane. The magnetization measurements reveal the presence of magnetic ordering around 2.3K and Cr-moments order ferromagnetically. The material is ordering in the vicinity of mean-field temperature very unusual for a frustrated kagome lattice type. Our data suggest that arrangement of magnetic moments in kagomé layers (intra and inter-layer interactions) might not purely either be ferromagnetic or antiferromagnetic, but a combination of both. However, under the application of magnetic field, $H=3$Tesla we obtain a fully saturated magnetic ground state. [R. Kumar and P.L. Paulose]

**Multiple magnetic transition in EuNiSi$_3$**

The Compounds of the intermetallic family RTX$_3$ (R is rare earth element, T is a transition metal and X is Si/Ge) show interesting magnetic properties like multiple magnetic transitions, metamagnetism and strong anisotropy due to crystal electric field effects. The Eu based compounds are important because interesting properties typical of rare earth compounds can be studied without crystal field effect. Moreover, $^{151}$Eu Mossbauer spectroscopy can be employed effectively to study valence state of Eu and to gain microscopic understanding of magnetic ground states. EuNiSi$_3$ is an interesting member of this series which orders magnetically. This behavior contrasts with related compounds EuNiSi$_2$, a valence fluctuating one and EuNi$_2$Si$_3$, a Pauli paramagnet. We find that this compound forms in non-centrosymmetric BaNiSn$_3$ type structure (space group I4mm). Previously this sample was reported to form in ThCrSi$_2$ type tetragonal structure (space group I4/mmm). We observe three distinct three magnetic transitions at 50K, 35K and 5.6K. The magnetic transition at 50K is antiferromagnetic while transition at 35K is ferromagnetic. Below 35K, ZFC and FC do not match as expected for ferromagnetic state. The estimated effective magnetic moment of 7.5 $\mu_B$ is typical of Eu$^{2+}$ ions. The Curie Weiss parameter $\Theta_B$ is +40K. Below 35K, ac susceptibility shows a distinct frequency dependent peak like in a spin-glass. This may be due to disorder in the system giving rise to competing
magnetic interactions. $^{151}$Eu Mossbauer spectra shows a single line at room temperature as expected for a paramagnetic state. The observed isomer shift is -8.6 mm/s which clearly shows that Eu is in 2+ state. We observe an increase below 50K indicating the onset of magnetic ordering. The estimated magnetic field is 32 Tesla at 40K. At 5K a clear splitting of lines is discernible and the hyperfine is 45T which is greater than the normally observed value of hyperfine field of 33 Tesla in many Eu based intermetallics. This indicates an extra contribution due to conduction electron spin polarization in addition to the core polarization term contributing to the Eu hyperfine field. [P.L. Paulose in collaboration with Dr. Sujata Patil, Wilson College, Mumbai]

**THz Spectroscopy**

We continued our efforts towards in-house fabrication of THz radiation sources and detectors using now photonic crystal like designs and putting TiO$_2$ based anti-reflection coating on substrate surface. The devices were tested on our in-house developed fast and robust setup for characterizing these devices. [Abhishek Gupta, Goutam Rana, S. Dattagupta (IIT-B), S. S. Prabhu]

We also developed using commercial software, enhancement of emitted THz using various thicknesses of TiO$_2$ layers and studied its effect on generation efficiency. [Abhishek Gupta, Rudheer Bapat, Goutam Rana, Arkabrat Bhattacharya, S. S. Prabhu]

Using commercial software, we are also developing various Metamaterial components for We are building Near Field Scanning THz Microscope (NSTM) for studying various near field patterns in the THz frequency region. [Arkabrat Bhattacharya, S.S. Prabhu]

We are also developing Continuous Wave (CW) THz spectroscopy setup. [Ravi Kumar Jain, S. S. Prabhu]

We are still developing codes for thin film n and k determination. Many programs were written and we are trying to optimize the algorithms now. [Jaydeep Watve, C. S. Garde (VIIT-Pune); S. S. Prabhu]

Stretchable THz filters and Band-polarizers on plastic material (PDMS). We are also making various analytical models for the same. [Siddhesh Ambhise, Shalom Palkhiwala, Arkabrat Bhattacharya, A.V. Gopal, S. S. Prabhu]

We have shown a 3-dimentional loop Yagi-Uda array that can be used for efficient, polarization independent and directional absorption of THz radiation over a narrow frequency range. The unit cell of the array consists of three vertically stacked gold micro-rings (director, feed and reflector) separated from each other by dielectric layer of sub-wavelength thickness. Plasmon hybridization among three rings yield a near zero transmission over a broad frequency range which enable the usage of Yagi-Uda as a band stop filter. Its ability to trap THz resonantly makes it potent for sensing and imaging applications. [with Arnab Pattanayak, Sandipta Roy, Goutam Rana, Siddhartha P. Duttagupta, Venu Gopal Achanta]

**Optical properties of Metallo-Dielectric structures**

Detailed numerical and experimental work is carried out to understand the origin of broadband response from plasmonic quasicrystals. For this Discrete dipole approximation and finite difference time domain simulations were carried out along with detailed statistical analysis on the distribution of holes in the pattern. [with Ajith P.R.]

Plasmon mediated modulation of conductivity of organic semiconductors is studied to establish the enhancement as well as to develop a model to explain the enhancement. Upto an order of magnitude enhancement in conductivity observed with both molecules that are resonant and non-resonant with the plasmon response. [with Aman Agarwal, Shilpa Samdhan, Satish Patil, IISc provided the organic molecules]

A 2-colour pump-probe setup is built to study the plasmon and exciton dynamics with < 50fsec time resolution. Simultaneous transmission and reflection measurements help establish the absorption phenomena [with Banjo K. Nayak and S. S. Prabhu].

Gold adhesion to any substrate is poor which results in degradation of gold based metamaterials. Also, due to
this poor adhesion, the nanofabrication processes are near impossible especially for lift-off based lithography. While conventional adhesive layers used in electronic industry are detrimental for plasmonics, a monolayer of MPTMS molecule is shown as a good adhesive layer that does not affect the plasmonic effects. However, the deposition techniques reported vary from 4 hours to 4 days. We have developed 2 fast deposition techniques and showed the layer compatibility with both dry etching as well as lift-off for large area pattern. We showed that MPTMS is good for a broadband covering visible to near-infrared wavelengths. [with Pushkar Gothe and Dhruv Gaur]

Initiated plasmon mediation in spintronics by starting with a theoretical model [with S. Dutta Gupta, University of Hyderabad].

Independently, measurements were performed on Pt to demonstrate spin Nernst effect [with A. Tulapurkar (IIT-B)].

**Members**


V. M. Chopde, K. B. Darje, D. R. Jadhav, Prasad Mundey, S.G. Pawar, Atul V. Raut, Santosh B. Shinde

**Research Scholars**


**Visiting Fellows**


**Junior / Senior Research Fellows**


**Administration**

Saleem Akhtar
National and International Involvement

**Arnab Bhattacharya**
1. Senior Member, IEEE, Associate Editor, Journal of Crystal Growth
2. Member, Board of Studies, Dept. of Physics, Indian Institute of Space Science and Technology, Trivandrum
3. Member, Syllabus committee for courses of Physics Dept. (autonomous), Mumbai University

**S. K. Dhar**
1. Member, Programme Advisory Committee (PAC) on Physical Sciences under Science and Engineering Research Board (SERB), DST, since September, 2015
2. Chief Vigilance Officer, TIFR, from August, 2015
3. Member, Low Temperature Facility Committee

**Achanta Venu Gopal**
1. Member, Indian delegation to BRICS working group on Photonics, Moscow
2. Member, Review Editorial Board of Frontiers in Physics
3. Member, Editorial Board of Scientific Reports
4. Associate Editor, Encyclopedia of Applied Physics
5. Senior Member, IEEE
6. Member, Optical Society of America (OSA) and SPIE
7. Co-ordinator, Indian side for the Global Photonics Network, an initiative of Osaka University

**A. K. Nigam**
1. Member, International Union of Pure and Applied Physics (IUPAP) Commission on Magnetism (C.9), from 1 January 2018
2. Co-Chairperson, Materials Research Society of India (Mumbai Chapter)
3. Member, Advisory Committee, International Conference on Magnetic Materials and Applications, Bhubaneswar, December 9 – 13, 2018
5. Subject Expert, Research and Recognition Committee for the subject of Physics, Faculty of Science and Technology, Savithribai Phule Pune University, Pune

**P. L. Paulose**
1. Member, International Advisory Committee (IAC), 'International Conference on HYPERFINE Interactions and their Applications' conference series

**S. Ramakrishnan**
1. Vice Chairman, IUPAP Committee (CS) on Low Temperature Physics, from Sept. 2014
3. Member, International Advisory Committee, International Conference on J-Physics (Solid State) held in Hachimatai, Japan, September, 2017
5. Member, Editorial board, Indian Journal of Cryogenics
6. Member, Planning and Monitoring board of Homi Bhabha National Institute, DAE, since January 2017
7. Member, Program evaluation Committee (Physics) of NISER, Bhubaneswar
8. Adjunct Professor, Indian Institute of Science Education and Research (IISER), Pune
9. Adjunct Professor, Jawaharlal Nehru Centre for Advanced Research, Bengaluru

**E.V. Sampathkumaran**
1. Member, Editorial Board, Solid State Communications
2. Member, Editorial Board, Scientific Reports (NPG)
5. Member, Editorial Board, Proc. Indian National Science Academy
6. Member, International Advisory Board, International Conference on Low Temperature Physics LT28
8. Member, National organizing committee of the conference on ‘Recent Advances in Strongly Correlated Systems’, Department of Physics, IIT Roorkee, February 8-10, 2017
9. Member, National Workshop on ‘Condensed Matter Physics in the last decade (WCMP-2017)’, Dept. of Physics, IIT Kharagpur, 3–5 February2017

**S. S. Prabhu**
Member, Optical Society of America (OSA)
Visits

*Achanta Venu Gopal*
1. Russian Quantum Centre, Skoltech, Moscow before the BRICS Working Group Meeting on Photonics
2. NTU, Singapore

*S. S. Prabhu*
1. Anaheim, USA, 9–13 April 2017

Invited Talks

*Arnab Bhattacharya*

*Mandar Deshmukh*
1. Mechanical modes of graphene drums and the strong coupling regime. EP2DS, Penn State University USA, 2 August 2017

*A. K. Nigam*
1. ‘Young Materials Researchers’ Meet (YMRM 2017), BARC, Anushakti Nagar, Mumbai, Dec. 10 – 11, 2017

*S. S. Prabhu*
1. Plasmonic Design Based Structures for THz Antenna Sources and Detectors. SPIE Conference on Defense and Commercial Sensing, Anaheim, California, USA, 9–16 April 2017
2. Plasmonic Sub-Micron Surface Modified Tera Hertz (THz) Sources, Global Nano-Photonics, 9-12 Dec 2017
3. THz Sources and Detectors for THz Spectroscopy. National Conference on Dielectric Relaxation and Spectroscopic Techniques 2017 (NCDRAST), Swami Ramananda Teertha University, Nanded, 14–15 December 2017
4. Tera-Hertz (THz) Devices: Sources and Detectors Made In India. ISRO Meeting on CMB Collaboration, ISRO, Bangalore, 8 January 2018
5. Material Modification and Characterization for Tera-Hertz (THz) Sources and Detectors. Keynote Address, NCRDMF, Sakharkherda, 14 January 2018
6. Applications of Tera Hertz (THz) Waves. Science Day Keynote Address, Institute of Science, Mumbai, 01 March 2018
8. Bulk, Surface and Antenna Design Modified Tera Hertz (THz) Sources and Detectors. 10th Asian Symposium on Intense Laser Science (ASILS10), Sharjah, UAE, 10–12 March 2018

*S. Ramakrishnan*
2. Unconventional superconductivity in ultrapure Bismuth crystal. International J-Physics conference, Hachimatai, Japan, September 2017
3. Superconductivity of ultrapure Bismuth. American Physical Society meeting, March 2018

*S. V. Sanpathikumar*
1. Magnetic and Transport Behavior of Metallic Kagome lattices, R$_3$Ru$_2$Al$_{12}$ (R= Rare-earths). Plenary talk, International Conference on Highly Correlated Systems, Kottayam, Kerala, 24–26 March 2017
Achanta Venu Gopal


6. Broadband Plasmonics. 11th India-Singapore Physics Meeting, NTU, Singapore, 4–7 March 2017


10. Towards planar integrated circuits. Raman Research Institute, Bengaluru, 4 April 2017

Conferences Organized by the Department

3rd Mumbai-Pune Semiconductors Meeting
TIFR Mumbai, 25 February 2017 (Organiser: Sandip Ghosh)

Indo German Training Workshops on Organic Electronics
UM-DAE-CEBS (Kalina, Mumbai), 2 December 2017; DY Patil Univ. (Belapur, Mumbai), 5 December 2017; HBCSE (Mankhurd, Mumbai), 6 December 2017 (Organisers: Arnab Bhattacharya and Amitabh Banerji, Institute of Chemistry Education, University of Cologne)

Non-DAE Research Projects

Mandar M. Deshmukh, R. Vijayaraghavan, A. Thamizhavel
Superconducting 2D materials and their nanoscale devices. Nanomission (DST), 2016 – 2019

Achanta Venu Gopal, V.I. Belotelov
Plasmonic quasicrystals for magneto-plasmonic studies. DST-RFBR, September 2016 – August 2018
Air shower analysis

An effort was initiated to accelerate the analysis of the GRAPES-3 EAS data under the ROOT based analysis framework to extract results on cosmic ray composition, cosmic ray anisotropy, diffuse γ-ray and point source search. The high density configuration of scintillator detectors in conjunction with the large area muon detector provides GRAPES-3 with a unique capability to measure EAS parameters extremely precisely in the TeV–PeV energy range. The GRAPES-3 has recorded over 10 billion EAS events since its operation began in 2000 and our recent simulations have shown that 50% of the recorded events are below 10 TeV due to its high density configuration. This low energy threshold is invaluable for the interpretation of the TeV γ-ray data.

Accurate gain and timing calibrations of scintillator detectors are two key parameters for obtaining precise estimate of shower size and direction. A new technique has been developed and successfully implemented that provides hourly calibration of equivalent single muons using the EAS data on a continuous basis (PoS(ICRC2017)356). The time offsets relating to the propagation delay of PMT signal in the 230 m long coaxial cable is now being accurately measured on hourly basis using another novel technique developed by us (PoS(ICRC2017)354). This method precisely accounts the diurnal variations in time offsets caused by the exposure of the signal cable to the daily temperature variation.

The energy of the primary cosmic rays is estimated from the experimental data using the shower size and energy relationship through simulations of the EAS in the atmosphere. A large data bank of EAS has been generated using full CORSIKA simulation with the help of the 1280 core GRAPES-3 computer cluster in the primary energy range of 1 TeV–10 PeV. A GEANT4 simulation framework for the GRAPES-3 scintillator detectors has been developed and a simulated database for different particle types such as electron, gamma, muon, proton, neutron and pion in the energy range of 1 MeV to 100 GeV has been created. The detector response with GEANT4 has been folded in the shower reconstruction analysis.

Each EAS is fitted with NKG lateral distribution function and minimization package MINUIT to obtain the core location, shower size and age parameters. A good agreement between the simulation and the observed data in terms of triggered detectors, total detected particles and shower size etc. was obtained validating the implementation of the simulation programs. Errors in the core location and shower size have also been calculated. The angular resolution of the array is being studied with precise time calibrations as mentioned before, after taking into account the effects of shower front curvature to improve angular resolution. Preliminary results show that the shower front curvature has a strong dependence on the shower age.

Was the cosmic ray burst detected by the GRAPES3 on 22 June 2015 caused by a transient weakening of the geomagnetic field or by an interplanetary anisotropy?

After publication of our work of transient weakening of Earth’s magnetic shield in Physical Review Letters (PRL 117 (2016) 171101), a group interpreted the occurrence of the same burst in a subset of 31 neutron monitors (NMs) to have been caused by an interplanetary anisotropy (IA), and not by transient weakening of geomagnetic shield. We reanalyzed the GRAPES-3 data in a different and more effective manner to test this alternative interpretation. We showed that the IA and the burst are two distinct phenomena, both of which were detected by the GRAPES-3. Further, our analysis could disentangle the contribution of both these phenomena and this new analysis clearly showed that the original interpretation of transient weakening of Earth’s magnetic field was the correct interpretation. By exploiting the multi-rigidity GRAPES-3 data we also explained why only 10 out of these 31 neutron monitors detected GRAPES3 burst while the rest of 21 did not, thereby clearly refuting the
HAGAR Observations

Analysis of HAGAR data

Very high energy gamma ray observations of various astronomical sources were carried out throughout this year using HAGAR telescope system located at Hanle in Ladakh. About 800 hours of data were recorded in various observational and calibration runs. Sources observed include several blazar class active galactic nuclei (Mkn 421, Mkn 501, 1ES 1011+496, 1ES 1218+304, 1ES 1959+650, BL Lac, 1ES 2344+514 etc) and pulsars (Crab, Geminga, PSR J1846+0919, PSR J2055+2539, PSR J0205+6449 etc). In addition to this, several observational runs were conducted for calibration purpose as well as to estimate systematic errors in the measured gamma ray flux. [S. Acharya, V. R. Chitnis, R. L. Deshmukh, P. Dorjey, N. Dorji, A. I. D'Souza, S. Duhan, K. S. Gothe, Mano Ranjan, B. K. Nagesh, N. K. Parmar, S. R. Patel, S. K. Rao, A. Sarkar, B. B. Singh, S. Upadhya and collaborators from IIA and SINP]

Crab nebula: This source, considered a standard candle for very high energy gamma ray astronomy, has been extensively observed by HAGAR. Analysis of data on Crab nebula from HAGAR collected over nine years period (October 2008 – December 2017) was completed. Total duration of data was 219 hours. Light curve of Crab was generated on time scale of month for better stability of signal. The average gamma ray rate was estimated to be 4.64 ± 0.23 (statistical) ± 0.13 (systematic) counts/minute for energy threshold of 230 GeV. The total statistical significance of 20σ was achieved using 219 hours of data. The time averaged flux was estimated to be (1.64 ± 0.09) × 10^{-10} photons cm^{-2} s^{-1} above 230 GeV. [B. Singh, R. J. Britto, V. R. Chitnis, A. Shukla, L. Saha, A. Sinha, B. S. Acharya, P. R. Vishwanath (IIA), G. C. Anupama (IIA), P. Bhattacharjee (SINP), K. S. Gothe, B. K. Nagesh, T. P. Prabhu (IIA), S. Rao, S. S. Upadhya]

Crab pulsar: Crab nebula is powered by a pulsar which is a highly magnetised neutron star. Data for Crab pulsar spanning duration of more 300 hours was analysed. The monthly ephemeris for Crab pulsar from Jodrell Bank CRABTIME data base was used. Each set of timing parameters obtained from this database is valid for a period of thirty days. For pulsed signal analysis, the absolute phase for each event was obtained using TEMPO codes in the prediction mode corresponding to HAGAR site, using contemporaneous pulsar elements. The absolute phases of events are grouped into phase bins and a phasogram is constructed. The preliminary result shows 6.3σ pulsed signal for energies above 230 GeV at CGRO-EGRET phase intervals. The measured pulsed component of the signal from the Crab pulsar is 0.48 ± 0.07 per minute, which is almost 10% of the nebular emission. [B. Singh, R. J. Britto, V. R. Chitnis, A. Shukla, L. Saha, A. Sinha, B. S. Acharya, P. R. Vishwanath (IIA), G. C. Anupama (IIA), P. Bhattacharjee (SINP), K. S. Gothe, B. K. Nagesh, T. P. Prabhu (IIA), S. Rao, S. S. Upadhya]

Mkn 421: This is a nearby blazar extensively observed and successfully detected by HAGAR. The source was reported to be in flare state in January 2018 by some
gamma ray telescopes. Target of opportunity observations with AstroSat were proposed and carried out in January 2018. Analysis of HAGAR data collected during this season was carried out, but no statistically significant signal was detected. Combined spectral fit is carried out for X-ray data from SXT and LAXPC onboard AstroSat and spectral energy distribution is generated. Further work is underway. [A. Sarkar, B. B. Singh, V. R. Chitnis, S. R. Patel]

**Multiwaveband studies of blazars**

Active galactic nuclei detected at gamma ray energies are predominantly blazars with jets directed towards us. Multiwaveband studies were carried out for couple of blazars during this year.

**Broad-band study of 1ES1959+650 in flare state:** 1ES1959+650 is a nearby (z=0.047) TeV blazar reported to be in flaring state during June–July 2016 by various gamma ray instruments. We studied multiwaveband data of this source spanning 800 days period including flare state. Multiwaveband lightcurves were generated analysing high energy gamma ray data from Fermi-LAT, X-ray data from Swift-XRT and UV data from Swift-UVOT and using publicly available X-ray data from MAXI, optical R band and polarization data from SPOL and radio data from OVRO. Several aspects were studied using these lightcurves and main findings include increase in variability from radio to X-ray and decrease in high energy gamma ray band on 10 days scale, good correlation between X-ray and high energy gamma ray data with zero lag, good correlation between radio and high energy gamma ray data with 68 days lag and hint of lognormality in flux distributions from various wavebands. Spectral studies indicated lognormal spectral shape in X-ray band with hardening of the spectrum with increase in flux. Whereas in the case of high energy gamma rays, such trend was seen only at lower energies, in 0.1–3 GeV band, but not at energies in the range of 3–300 GeV. Multiwaveband spectral energy distributions (SEDs) were generated for various stages of flare state and also for quiescent state. These SEDs could be not be fitted satisfactorily with single zone synchrotron self-Compton (SSC) model, but could be described well with two zone SSC model indicating two emission zones in jet responsible for multiwaveband emission. Inner zone is responsible for synchrotron peak and high energy gamma ray part of the SED. Whereas second zone was required to produce less variable optical-UV and low energy gamma ray emission. [S. R. Patel, A. Shukla (Wurzburg University), V. R. Chitnis, D. Dorner (Wurzburg University), K. Mannheim (Wurzburg University), B. S. Acharya, B. J. Nagare (Mumbai University)]

**Short time-scale gamma ray variability in CTA 102:** The flat spectrum radio quasar CTA 102 (z=1.037) was detected in enhanced state of activity across the entire electromagnetic spectrum during 2016–17. Major outburst was seen from this source during December 2016 – May 2017. On 19 April 2017 Fermi-LAT observed a flux of (2.2 ± 0.2) × 10^-5 ph cm^-2 s^-1 at energies above 100 MeV during a single orbit. During this orbit we detected significant (4.7σ) flux variations down to the timescales of ~5 minutes. This variability timescale is much shorter than the light-travel time across the central black hole (~ 70 minutes) indicating a very compact emission region within the jet. This short time scale variability is unexpected as there is no indication of gamma ray attenuation by pair creation with photons in broad emission line region, thereby indicating these photons to originate far from black hole. This observed fast variability can be interpreted in terms of dissipation of magnetic islands. Alternatively it could be due to protons in a collimated beam from the base of the jet encountering the turbulent plasma at the end of the magnetic nozzle. [A. Shukla (Wurzburg University), K. Manheim (Wurzburg University), S. R. Patel, J. Roy (CEBS, Mumbai), V. R. Chitnis, D. Dorner (Wurzburg University), A. R. Rao, G. C. Anupama (IIA), C. Wendel (Wurzburg University)]

**Geiger-mode avalanche photodiode (G-APD) based camera**

Work on proposed 256 pixel G-APD based imaging camera for 4m class telescope progressed well during this year. In this camera, entire electronics will be mounted behind G-APD pixels. Modular design is adopted for front end electronics. Each module, called Pixel Cluster Module (PCM), will consist of 16 G-APD pixels and associated front end electronics which includes pre-amplifiers, temperature compensated bias supplies and low voltage supply cards. In front of G-APDs, light concentrators will be mounted to remove dead space between the pixels and also to cutoff any stray light falling on the camera. Field of view of each pixel will be 0.3° × 0.3° and that of camera will be 4.8° × 4.8°. Behind PCMs, back end electronics will be mounted to provide pulse conditioning, trigger generation, digitization and recording of data. Dynamic range of 1–1000 photo-electrons per pixel will be covered using low gain and high gain channels.
Highlights of the work carried out during last year on various aspects of the camera are given below:

**Front end electronics:** Improved version of 4-pixel pre-amplifier was designed to reduce pulse pileup due to night sky background, to provide enable/disable feature for sub-pixels to facilitate the pixel gain calibration and to improve signal-to-noise ratio at a single photo-electron level. The performance of this new circuit was evaluated and production of four such cards, which will be integrated into a prototype PCM is underway. Two bias boards supplying bias for 16 pixels are fabricated and will be integrated with PCM. These boards are interfaced to a single board computer (Raspberry Pi) in a daisy chain fashion and are being tested. The 3D modelling of the final design for PCM housing is under progress. Various surface geometries for light concentrators were studied using softwares ROBAST and Zemax. Also different concepts for design and fabrication of the light concentrators are being reviewed.

**Back end electronics:** This consists of a crate housing digitizer, trigger and data concentrator modules. The event data recorded by the back end electronics is sent to PC via two dedicated 1 Gbps Ethernet links. All the modules are designed around FPGAs. Each digitizer module accepts the signals from PCM and routes them through two channels with different gains to cover the entire dynamic range. It also generates pixel level trigger and digitizes the amplified pixel signals on receiving the final trigger from trigger module. This module has four Domino Ring Sampler (DRS) based mezzanine digitizer boards and sends event data packets to data concentrator over dedicated serial links. The mother board as well as mezzanine Digitizer board has been fabricated and being tested. Data concentrator module is also fabricated, FPGA coded and is ready for use. Trigger module generates trigger based on pre-selected criteria in the form of at least neighbouring ‘n’ pixels with pulse height above ‘m’ photo-electrons, where ‘n’ and ‘m’ will be programmable. Apart form this, trigger module will also control overall operation of camera and monitor its health. Design specifications for trigger module are being worked out.

**Software development:** Several software programs were developed to help in assessing the performance and improving the design of the hardware circuits. Overall scheme of the software architecture for the final camera was worked out. Also some GUI based applications to manipulate data base, display pulse profiles from pixels etc were developed and are ready to be integrated with rest of the software.

**G-APD characterization:** It is necessary to understand response of each of the G-APDs which will be used in the camera. Parameters which are particularly important are breakdown voltage and its temperature dependence. A test bench consisting of ultra-fast CAEN LED light source, amplifier, temperature controlled bias circuit and VME digitizer was setup. Environmental chamber was used to vary the temperature over -20° to +30° Celsius in order to study temperature dependence of breakdown voltage. Uniformity of G-APD gain over this temperature range by controlling bias voltage was confirmed. The absolute gain of few G-APDs was estimated using single photo-electron measurements and its linear dependence on applied bias voltage was studied.

**Monte Carlo Simulations:** Simulations for expected performance parameters for 4m class telescope with G-APD based camera were carried out for Hanle location. Extensive air showers initiated by gamma rays and cosmic rays were simulated using CORSIKA package and were passed through the detector simulation program which takes into account various design details of the camera and telescope. 5σ detection sensitivity, which gives ability to reject cosmic ray background retaining the gamma ray signal, was estimated. Static supercut method with Hillas image parameters was used. Estimated sensitivity corresponds to observation duration of 4 hours to detect Crab nebula at 5σ significance level at energy threshold of 230 GeV. About 8% improvement was seen in sensitivity using the Time RMS parameter along with the image parameters. The implementation of dynamic supercut method which takes into account energy dependence of some of the Hillas image parameters, was initiated. [S. Acharya, V. R. Chitnis, R. L. Deshmukh, P. Dorjey, N. Dorji, A. I. D’Souza, S. Duhan, K. S. Gothe, A. P. Krishnan Kutty, Mano Ranjan, B. K. Nagesh, N. K. Parmar, S. R. Patel, S. S. Poojary, S. Rao, M. N. Saraf, A. Sarkar, B. B. Singh, S. S. Upadhya, P. Verma]
Gravitational wave science and LIGO-India

The analysis of data collected by the LIGO and Virgo gravitational wave detectors during the second observing runs continued by the LIGO Scientific Collaboration. The detectors are in the upgrade mode for about a year. A significant result is the estimate of the Hubble constant using the GW signal from the binary neutron stars merger GW170817 and its optical identification in the galaxy NGC4993. The deduced value is 70 km/s/Mpc, with about 15% error, from a single gravitational wave event. This is between the neighborhood estimate from supernovae and the cosmological estimate from cosmic microwave background. As more such detections accumulate, GW signals will aid in a precision independent estimate of the Hubble constant. The preparation of land at Hingoli, Maharashtra for housing the gravitational wave detector LIGO-India, has begun. The construction activities for the laboratory are expected to start next year. [C. S. Unnikrishnan]

Gravitational waves propagate at the speed of light in general relativity, because of its special relativistic basis. However, light propagation is linked to the electromagnetic phenomena, with the permittivity and permeability constants $\varepsilon_0$ and $\mu_0$ as the determining factors. Is there a deeper reason why waves in a geometric theory of gravity propagate at a speed determined by electromagnetic constants? What is the relation between gravity’s own constants and the speed of gravitational waves? We have answered this question by estimating the speed of the gravitational waves purely from the experimental data on measurements of the gravitational interaction between masses and masses with angular momentum. The equivalent of $\varepsilon_0$ (Coulomb constant) is the inverse of the gravitational constant, $\varepsilon_G = 1/G$. The analogue of magnetic constant (Ampere) $\mu_0$ was found in the gravitomagnetic interaction between the rotating earth and a space borne gyroscope in the Gravity Probe B experiment. The interaction is similar to that of two magnetic dipole moments, leading to the Lense-Thirring precession. From the measured precession rate of $37\pm7$ milli-arcsec/year, we deduced that $\mu_G = (6.7 \pm 1.3) \times 10^{-28}$ m/kg. Thus the square of the speed of the gravitational waves was estimated from gravito-statics as:

$$c_G^2 = G / \mu_G = (9.9 \pm 1.9) \times 10^{16} \text{ m}^2/\text{s}^2$$

[C. S. Unnikrishnan with G. T. Gillies of University of Virginia]

Quantum Hall Effects and Gravity

Cosmic Relativity is a new paradigm for relativity, dynamics and the theory of gravity. It is based on the empirically well-supported assertion that all relativistic effects are in fact the gravitational effects of the matter-energy in the universe. Among the several physical consequences, the effects on quantum systems are particularly important. The effect of cosmic gravity on the cyclotron orbits of the electrons in the two dimensional system and the possibility of finding a unified single particle theory for both integer and fractional quantum Hall effects was indicated in an earlier report. Now we have reliable proof that this is indeed the case, based on the quantum mechanical effect of the interaction of the electron spin and the cosmic gravitomagnetic field seen by the electrons in the cyclotron orbits. (Another important effect based on the energy difference between the two projections of spin reflecting in the spin-selective electron transport in chiral biomolecules was reported earlier.)

In the electron cyclotron orbits, the quantum phase of the electrons change due to the interaction of the charge with the magnetic vector potential ($eA$) as well as due to the interaction of the magnetic moment with the applied magnetic field. For closed orbits, the quantum condition that the net phase is an integer times $2\pi$ should be obeyed. This is violated for a single electron; with its half-integer spin, the phase per orbit is $\pi$. The problem does not arise for a pair of electrons, as in superconductivity. The solution is to recognize the additional interaction of the spin with cosmic gravitomagnetic field, which provides exactly the phase change required to render the total phase an integer times $2\pi$. With the strength of this proof we are now completing the universal theory of quantum Hall effects, with both the electromagnetic and cosmic gravitomagnetic fields determining electron dynamics. The fractional quantum Hall effect is not fundamentally different from the integer quantum Hall effect. [C. S. Unnikrishnan]
Quantum Optics

Quantum optics is well established theory. It postulates vacuum modes of radiation at all frequencies, with the zero point energy \( \frac{\hbar \omega}{2} \). This leads to a severe conflict with cosmology, because even a much smaller energy density leads to unreasonably large rate of expansion of the universe. However, quantum optics needs the quantum vacuum because it explains some of its most essential physical effects invoking these vacuum modes. One such elementary, yet universal, situation is the quantum noise measured when a beam is split at a beam splitter.

The usual scheme of balanced homodyne uses two detectors D1 and D2 to receive light split into two with a 50:50 beam splitter BS. The final output is the difference of the two signals, which should be zero with only the coherent input \( |C\rangle \), with average intensity N photons. But, an irreducible noise \( \sqrt{N} \) is measured. Quantum optics theory explains this by asserting that the vacuum mode \( |0\rangle \) and its fluctuation enter through the open port of the beam splitter. Since there is an additional phase difference of \( \pi \) between the transmitted and reflected beams, this noise remains even after the subtraction.

We devised a novel homodyne scheme, where the wave front, rather than the amplitude, is split and detected in two detectors (see figure, right panel). Since the crucial phase factor \( \pi \) is now absent, subtraction should give zero residuals. The difference signal has no contribution from the vacuum noise, but we measure a quantum noise that is identical to the noise in beam splitter homodyne scheme. Therefore, the standard picture of vacuum mode mixing as the cause of quantum noise is incorrect -- there are no vacuum modes of radiation. This eliminates the problem of the large cosmological constant, in the context of quantum electrodynamics. More refined experiments are underway. [Ninad Jetty and C. S. Unnikrishnan]

Optics in high finesse solid and liquid microspheres

The experimental facility to manufacture high finesse silica microspheres and high quality tapered optical fibers to couple and detect evanescent modes of light is fully ready. Both a CO2 laser and a controlled hydrogen-oxygen flame is being used for the fabrication. The experimental set up is now isolated from vibrations, air currents and microdust to a level adequate for delicate experiments. Both silica microspheres and liquid microspheres supported on shaped optical fibers are brought near the tapered fibers with piezo-stages, to a separation between 0 to 500 nm, to efficiently couple the evanescent modes. The immediate goal is experiments with the liquid microspheres to probe physical effect in time dependent dynamical optical cavities with high finesse [Meenakshi Gaira]

Cold atom matter-wave interferometry

We are in the process of setting up an atom-interferometer useful for the high precision measurements of gravity, rotation and acceleration. The first stage of the source of laser-cooled atoms is set up and tested. This consists of 2D+ magneto-optical trap (MOT) for Rubidium atoms, in a compact ultra-high vacuum system. The setup has a differentially pumped SS chamber for a 3D MOT and a glass chamber for the interferometry. The laser beams required for the experiment are fiber coupled from very stable external cavity diode lasers, locked to the atomic transitions.

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Members


Research Scholars

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Junior / Senior Research Fellows
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Auxiliary staff

National and International Involvement

V. R. Chitnis
Co-convenor, National Symposium on VHE Gamma Ray Astronomy, GOALS, Mt. Abu, 16–18 November 2017

B. Hariharan
Chief Guest, ‘Kids ask Scientists’, Regional Science Centre, Coimbatore, 25 March 2018

P. K. Mohanty
Member, International Scientific Programme Committee (ISPC) of ICRC 2017, Busan, South Korea, 12–20 July 2017

C. S. Unnikrishnan
Member, Council of the IndIGO consortium for development of gravitational wave research in India, a member of the LIGO-Scientific Collaboration (LSC) and a member of LSC council.
Invited Talks

Anuj Chandra
Extending the range of particle densities observed by GRAPES-3. 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea, 12–20 July 2017

V. R. Chitnis
3. VHE Gamma Ray Astronomy with HAGAR Telescope Array. Advances in Particle Physics and Cosmology (AAPCOS-2018), Saha Institute of Nuclear Physics, Kolkata, 6–9 March, 2018

S. K. Gupta
1. Expansion of the GRAPES-3 extensive air shower array, and expected performance. 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea, 12–20 July 2017
2. Talk on behalf of C4, 29th General Assembly of the IUPAP, Sao Paulo, Brazil, October 2017

B. Hariharan,
Effects of atmospheric electric field on muon intensity observed in GRAPES-3 experiment. 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea, 12–20 July 2017

P. K. Mohanty
Transient weakening of geomagnetic field probed by GRAPES-3. 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea, 12–20 July 2017

Meeran Zuberi,
Dependence of the GRAPES-3 EAS trigger rate and particle density on atmospheric pressure and temperature. 35th International Cosmic Ray Conference (ICRC2017), Busan, South Korea, 12–20 July 2017

Conferences Organized by the Department

National Symposium on Particles, Detectors and Instrumentation (NSPDI)
TIFR, Mumbai, October 4 – 7, 2017

National Symposium on VHE Gamma Ray Astronomy (NSGRA-2017)
GOALS, Mt. Abu, November 16 – 18, 2017 (Jointly organised with BARC)

25th International Conference on Supersymmetry and the Unification of Fundamental Interactions (SUSY17)
TIFR, Mumbai, December 11 – 15, 2017
Intense Field Physics

Ion Acceleration

Acceleration of Negative Ions in Intense Laser Plasma Experiments

An 800 nm, 30 fs laser with an intensity of $1.5 \times 10^{18}$ W/cm$^2$ was used to accelerate ions from the irradiated surface of a solid target. The angle of incidence was kept at 45° with $p$-polarization. Ions accelerated from the irradiated surface were characterized using a Thomson parabola spectrometer (TPS) placed along the target normal direction. A micro-channel plate (MCP) was used as the detector in the TPS which was imaged by a 12-bit CCD camera to record the signal. The MCP had a provision to be controlled by a fast electronic switch to detect ions of a particular species based on the ion arrival time. The target was a 5 mm thick Al coated BK-7 glass with a coated thickness of 100 nm. The laser was focused on the coated surface and ions accelerated along the target normal was studied. The focus of the experiments were on the generation of H$. The accelerated ions propagated through a vacuum of $9 \times 10^{-5}$ mbar for 63 cm and then $7 \times 10^{-7}$ mbar for 73 cm before they reach the detector. The pressure of the chamber was measured away from the direction of the plasma plume and the gauge did not show variations in the chamber pressure when the laser was incident on the target.

Generation of negative ions when high contrast ($10^{-9}$), high intensity ($> 10^{18}$W/cm$^2$) laser pulses are focused on the surface of metal (Al-coated glass) is observed. Contrary to the expectations, we observe H$^{−}$ ions at the target front with energy extending up to about 80 keV. The observation is feasible due to the improved signal-to-noise ratio by a gating technique adapted in Thompson parabola spectrometry where the detector is switched on only at the specific time period when H$^+$ or H$^+$ are expected to reach the detector. For the laser intensity, pulse duration and pulse contrast used in this experiment, the pre-plasma scale length is anticipated to be small and the electron temperature is high. Computations show that under such conditions the possibility of charge reduction of protons to form H$^-$ is not possible in the plasma plume. We propose that charge reduction of the protons occurs along the path to the detector when the high energy protons co-propagate with the low energy electrons. Along the path, the centre of mass velocity is low, the interaction time is large to facility electron-ion recombination to form H. Negative ions are crucial in conventional tandem accelerators. They offer the possibility to derive maximum energy from the electrostatic potentials applied in the acceleration columns. Hybrid methods of combing laser plasma acceleration with the conventional methods are under exploration recently. The possibility of generating negative ions from a laser plasma accelerator could be of interest in such a perspective, apart from the basic curiosity of generating fast negative ions and probing the science of their generation. [Sheroy Tata, Amit D. Lad, Angana Mondal, and M. Krishnamurthy]

Using Pre-Pulse and External Magnetic Fields to Control the Neutralisation of Accelerated Ions

In order to control the neutralisation of accelerated ions during intense laser solid interactions, (i) we used pre-pulse to reduce the flux of accelerated neutral particles. This effectively increases the neutralization of other ion species. Using the gated Thomson Parabola Spectrometer we were able to observe modulations in the ratio of neutralization in heavy ions ($C_6^+$). (ii) We also used external magnetic fields along the path of the ion motion significantly change in the spectrum of neutral particles detected at the detector. Neutral particles if produced by a co-moving layer are seen to be affected by the presence of a magnetic field of ($\sim$1.8
KG) at the target surface. Further it is thought, due to various charge species being accelerated from the plasma at various times, the neutralization is modulated depending on the velocity of the charge state (the time in the field and the interaction volume). [Sheroy Tata, Amit D. Lad, Angana Mondal, and M. Krishnamurthy]

High Energy Density Physics

**Dynamics of Plasma Reflectivity at the Rear of Thin Foils Irradiated by High Intensity, Femtosecond Laser Pulses**

The experiment was performed with our 100 TW laser system. A p-polarized laser pulse of 25 femtosecond duration was focused with an f/3 off-axis gold coated parabolic mirror to a 10 µm spot on the target at 45° angle of incidence, creating a laser intensity of $\left(3 \times 10^{19}\right)$ W/cm². The laser contrast (picosecond pedestal / peak intensity) was $1 \times 10^{-10}$ ensuring minimal pre-plasma. Al-foils of 12 µm and 5.5 µm thickness were used as targets. The target was mounted on a computer controlled X-Y stage to translate the target so that the interaction laser pulse hits a fresh spot at each time. A small fraction (5%) of the main interaction pulse was extracted with the help of a beam-splitter to generate the 2ω probe (400 nm) with a BBO crystal. The time delay between the main interaction laser pulse and the probe pulse was controlled (precision of 3.3 fs) with the help of a computer controlled delay stage.

**Measurement of Electric Field Produced by Energetic Electrons in Intense Laser Matter Interactions**

The experiment was performed using our 100 TW laser system. The laser (800 nm, 1 J, 25 fs) was focussed to an intensity of $3 \times 10^{19}$ W/cm² on solid wedged targets (e.g. blade). The sharp wedge of the blade is also coated with nanoparticles to enhance the laser absorption and subsequently the electron flux and energy. The electro-optical sampling (EOS) system is employed using of a 200 µm-thick ZnTe electro-optic crystal installed 1 mm downstream the target. Being this distance much larger than the Debye length only the highly energetic ejected electrons that escape the potential barrier are able to reach crystal. A time-delayed probe laser, derived from the main laser, illuminates the crystal while simultaneously the electron cloud is moving below it. The birefringence created in a crystal rotates the polarization of the probe pulse. By measuring the polarization angle we can estimate the induced electric field at the crystal. By varying the probe-pulse delay

![Time resolved reflectivity at the rear side of (a) 12 µm and (b) 5.5 µm Al-foil. The initial fall of reflectivity is due to the fast electron induced ionization that creates a low density plasma, which absorbs the probe. A rise in the reflectivity at later times (30 ps) which is attributed to shock induced ionization.](image)

The simultaneous arrival of the pump and the probe pulse on the target defines the beginning of time ($t = 0$). The 2ω probe was focused to a 75 µm diameter spot to image the rear plasma. The probe pulse was appropriately attenuated to ensure that it did not create plasma. We use photodiodes as well as charged coupled device (CCD) cameras for the reflected probe beam, the latter for space resolved (spatial resolution 5 µm) images of the target rear. Fig. (a) shows the 2ω probe reflectivity from the rear of a 12 µm Al-foil. The time $t = 0$ is defined as that instant at which reflectivity starts falling. At negative times, the probe pulse gets reflected from cold target, whereas after $t = 0$, the probe gets reflected from the plasma. The reflectivity falls to 30% within 20 ps with a time constant $t_1 = 12.9$ ps. There is a prominent rise in the reflectivity to 80% at a 30 ps probe delay, and a decrease in the next 30 ps with a rate $t_2 = 7.8$ ps. The subsequent rise in reflectivity can be explained by considering shock induced ionization. The average shock speed can be considered ~ $4 \times 10^6$ cm/s and the shock reaches the target rear 30 ps after its launch at the target front, consistent with the timing of this reflectivity rise. [Moniruzzaman Shaikh, Amit D. Lad, Kamalesh Jana, Deep Sarkar, Sudipta Lodh Roy, and G. Ravindra Kumar]
with respect to the electron bunch arrival at the target, we can study the ultrafast dynamics of the electric field. Also by measuring the polarization modulation of the probe laser, the main properties of the emitted electrons (charge, energy, temporal profile) are retrieved.

This experiment is collaborative effort with Ricardo Pompilli, Fabrizio Bisesto, Laboratori Nazionali di Frascati, Italy; and Arie Zigler of Racah Institute of Physics, Hebrew University, Jerusalem, Israel. [Amit D. Lad, Kamalesh Jana, Moniruzzaman Shaikh, Deep Sarkar, Sudipta Lodh Roy, and G. Ravindra Kumar]

**Probing Ultrafast Dynamics of Solid-Density Plasma Generated by High-Contrast Intense Laser Pulses**

The main pump beam was focused by an f/4 off-axis parabolic mirror to a 35 µm focal spot (FWHM) on an optically polished (λ/10) BK-7 glass target at a 45° angle of incidence. The peak intensity was 4 × 10^{18} W/cm^2. A motorized high-precision stage was used to move the target so that every laser pulse interacted with a fresh position on the target. A small fraction of the main laser beam was extracted and up-converted to its second harmonic (400 nm) by a BBO crystal and used as the probe pulse. A BG-39 filter was used after the BBO crystal to remove the residual 800 nm light in the probe. The probe was focused onto the plasma at normal incidence to a 120 µm focal spot (FWHM). The probe intensity was kept low (4 × 10^{10} W/cm^2) so that it did not ionize the target. Spatial overlap between the pump and the probe beams was ensured by high resolution imaging. The probe beam was time-delayed with respect to the pump beam using a high precision motorized retro-reflector delay stage. The reflected probe was collected by a lens and then split into two parts. One part went to a high-resolution (0.35 Å) spectrometer (OOI, HR-2000) to record a spectrum at each time delay. The other part of the beam was fed to a photo-diode (PD) which measured probe reflectivity at each time delay.

Experiments show a rapid rise in blue-shift at early time delay followed by a rapid fall and then a slow rise in blue-shift at later time delays. These results are contrary with our earlier experiments with low contrast laser system. Simulations show that the early-time observations, specifically the absence of any red-shifting of the reflected probe, can only be reproduced if the front surface is unperturbed by the laser pre-pulse at the moment that the high intensity pulse arrives. A flexible diagnostic that is capable of diagnosing the presence of low-levels of pre-plasma formation would be useful for potential applications in laser-produced proton and ion production such as cancer therapy and security imaging. [Kamalesh Jana, Amit D. Lad, Moniruzzaman Shaikh, Deep Sarkar, Sudipta Lodh Roy, and G. Ravindra Kumar]

**Faraday Rotation Technique of Mega-gauss Magnetic Fields produced in Laser-Plasma Interactions**

A p-polarized laser pulse of 25 femtosecond duration was focused with an f/3 off-axis gold coated parabolic mirror to a 10 µm spot on the target at 45° angle of
incidence, creating a laser intensity of \((3 \times 10^{19} \text{ W/cm}^2)\). Optically polished bulk aluminium slabs were used as targets. The target was mounted on a computer controlled X-Y stage to translate the target so that the interaction laser pulse hits a fresh spot at each time. A small fraction (5\%) of the main interaction pulse was extracted with the help of a beam-splitter to generate the 2ω probe (400 nm) with a BBO crystal. The time delay between the main interaction laser pulse and the probe pulse was controlled (precision of 3.3 fs) with the help of a computer controlled delay stage. The p-polarized (extinction ratio \(5 \times 10^{-2}\)) probe was incident perpendicular to the target normal to capture expanding plasma and the characteristics of the transmitted probe to measure self-generated magnetic field. Faraday rotation is the rotation of the plane of polarization of an electromagnetic wave when it passes through a magnetic field. The polarization of transmitted probe was measured with the help of two polarizers (which are perfectly cross each other, extinction ratio \(5 \times 10^{-2}\), in absence of pump pulse.)

The pump pulse irradiates a target and creates a plasma. The magnetic fields induce a birefringence in the plasma, resulting in a change in the polarization state of the incident probe, which depolarizes the transmitted beam. By measuring the angle of rotation we can infer the magnitude of the self-generated magnetic field. Presently we are in the process of analysing the data fully. The initial calculations suggest the existence of mega-gauss magnetic fields. [Kamalesh Jana, Amit D. Lad, Moniruzzaman Shaikh, Deep Sarkar, Sudipta Lodh Roy, and G. Ravindra Kumar]

**THz Absorption Spectrum using Monolayer Graphene**

We studied THz absorption spectra of monolayer graphene. Energetic (> 1 µJ) THz radiation was generated by two-colour filamentation. The THz radiation was collected and focused by off-axis parabolas to a focal point of ~ 1 mm diameter resulting in electric fields > 100 kV/cm (for ~ 1 ps pulse). The monolayer graphene sample (on HRFZ Si) was scanned along the focus (open aperture Z-scan) to obtain THz electric field intensity dependent transmission. A similar scan was performed on the plain HRFZ substrate as reference. Absorption spectra at focus and away from focus were obtained from Michelson interferometry. [V. Rakesh Kumar, Kamalesh Jana, Moniruzzaman Shaikh, Deep Sarkar, Sudipta Lodh Roy, Amit D. Lad, and G. Ravindra Kumar]

**Optical Sciences**

**Lifetime distributions of Anderson localized random lasers**

We had earlier obtained pulsewidth distributions from Anderson localization lasing in an array of microresonators. A theoretical model was also constructed to understand the experiments. Now, we have utilized the insights provided by the model to actually devise a technique to measure the natural lifetimes of the lasing cavities. Note that this is a more fundamental parameter (lifetime) than the pulsewidth. We have also correlated the distribution of lifetimes to the critical disorder in one dimension. [Krishna Chandra Joshi, Randhir Kumar, M. Balasubrahmaniyam, Sushil Mujumdar]

**Measurement of critical disorder in one dimensional systems**

It is known that single parameter scaling is violated below a certain disorder strength, known as the critical disorder. It is extremely difficult to measure the critical disorder because (a) it is very weak in nature, and (b) it needs configurational averaging. Our system of an array of microspheres turned out to be the ideal structure, in which we directly estimated the Lifshitz tail, and then identified the critical disorder. [M. Balasubrahmaniyam and Sushil Mujumdar]

**Photonic crystal lasing from novel nanoparticles**

A collaborative effort was launched with Prof V Polshettiwar in DCS. The lab fabricates novel morphologies of nanoparticles. We fabricated photonic crystals from the novel particles, and impregnated the samples with a lasing dye, and thereafter obtained efficient lasing when the crystal bandgap overlapped the dye emission cross-section. The novel feature here was the ability to tune the bandgap using fiber density of the particles. [Ayan Maiti, Vivek Polshettiwar and Sushil Mujumdar]
Nuclear Dynamics

(Non-)hydrodynamic modes and entropy production

Investigation of the evolution of hydrodynamic and non-hydrodynamic moments of the distribution function may provide useful information on the conserved macroscopic quantities. Within the analytically solvable Bjorken and Gubser flow profiles, the evolution of various macroscopic observables were studied within the (perturbative) third-order Chapman-Enskog approach and the (non-perturbative) anisotropic hydrodynamic approach. The results were compared with the exact solution of the Boltzmann equation with collision term in relaxation time approximation.

While the evolution of the hydrodynamic moments of the distribution function (i.e. of the energy momentum tensor) was well reproduced by both the hydrodynamic approaches, the entropy production was demonstrated to be a sensitive discriminator between different hydrodynamic approximations and exhibited much larger deviations from the exact solution of the Boltzmann equation for several hydrodynamic observables. This was traced to large contributions from non-hydrodynamic modes coupling which were not well captured by the hydrodynamic approximations. The differences with the exact solution were found much more for Chapman-Enskog hydrodynamics than for anisotropic hydrodynamics as the latter resums some of the dissipative effects from anisotropic expansion to all orders in the anisotropy. In fact, the anisotropic hydrodynamics provided the most precise macroscopic description for the highly anisotropically expanding systems. [C. Chattopadhyay, U. Heinz, S. Pal, G. Vujanovic]

Analytical attractors solutions in causal relativistic dissipative hydrodynamics

The commonly accepted paradigm for the application of hydrodynamics is that the system should be close to thermodynamic equilibrium. In contrast, recent experimental observations suggest that strongly interacting matter produced in small collision systems has liquid-like behavior. In fact, for systems that are far-from-equilibrium, dynamical hydrodynamic attractor solutions may prevail within the realm of kinetic theory and holography in systems having large symmetry. For an in-depth understanding, the Bjorken and Gubser flow profiles were considered, which, are the two well-known analytic solutions for relativistic (first-order) Navier-Stokes equations. For the causal second-order Müller-Israel-Stewart and the third-order Chapman-Enskog dissipative hydrodynamic evolution equations, general analytical solutions were obtained within the Bjorken and Gubser flow profiles for a system with vanishing bulk viscosity and chemical potential, and having a constant shear relaxation time. The hydrodynamic attractors were then analytically determined for such systems by studying the universal behavior of these solutions at late times where all informations about the initial conditions are lost. Finally, the properties of these hydrodynamic attractors were studied for transport coefficients obtained from relativistic kinetic theory in the relaxation-time approximation. In particular, the common expansion methods used to characterize the attractor properties in a fluid, namely the gradient expansion showed asymptotic convergence while the slow-roll series expansion, though had zero radius of convergence at initial times, lead to a reasonable description at late times. [S. Jaiswal, C. Chattopadhyay, A. Jaiswal, S. Pal]

Nuclear Physics

Feasibility Study of Sn Bolometer for Neutrinoless Double Beta Decay in $^{124}$Sn

The R&D towards a Sn cryogenic bolometer prototype for study of neutrinoless double beta decay ($0\nu\beta\beta$) is in progress. In order to understand various factors affecting bolometer performance, a test setup with a well-studied absorber material (Sapphire) was designed and tested. Heat pulse measurements were carried out both in CFDR-1200 and a conventional wet refrigerator of µK setup to assess the impact of vibration due to pulse tube cooler.

The CFDR-1200 has a provision to fit a linear drive unit to the pulse tube motor head, in lieu of the standard stepper motor drive. This reduces vibrations at low temperature. The vibrational noise was further reduced by detaching the valve motor control unit from the cryostat and hanging it from the ceiling. For low temperature measurements, special attention needs to
be paid to ground loops and pickups. In spite of enclosing the whole setup in the Faraday cage, the electrical noise was found to be fluctuating and was significantly high (e.g. $-30$ dB at 50 Hz). A systematic and detailed analysis of the noise was carried out using the NI based DAQ. From the FFT of measured noise spectra at different temperatures on different thermistors, the noise sources could be identified and were shielded/eliminated to the extent possible resulting an improved noise level of around $-60$ dB at 50 Hz. Additionally, the STILL/IVC/OVC pirani pressure gauges (Pfeiffer Make) and remote communication device (RS232 to USB adapter) were found to contribute the noise band at around $-16$ kHz, in spite of the use of the optical isolators. The replacement of RS232-USB adapter with a different version and disconnecting the pressure gauges during the measurement resulted in almost complete elimination of this high frequency noise.

Due to reduction in the overall noise, an improvement was observed in the lowest temperature of the mixing chamber ($\sim 5.6$ mK as compared to earlier 7 mK). Similar improvement was also seen in the NTD Ge sensor on the Sapphire bolometer. Prior to electronic noise reduction, the NTD sensor DB27 on the bolometer was found to deviate from expected Mott-like ($\log R \propto T^{0.5}$) behaviour at $T > 100$ mK. After the above improvements the sensor showed significant improvement with Mott-like behaviour ($\log R \propto T^{0.5}$) down to 70 mK. However, the sensor can be used upto 20 mK, where the sensitivity ($dR/dT$) is in usable range. The $R$ vs $T$ in the range 20-70 mK is fitted to an empirical function. It was also verified that $R_{\text{max}} \sim 2G\Omega$ at mK temperature can be measured and is not limited by the insulation of the readout wiring.

A pulse height analysis algorithm based on Savitzky-Golay filter has been developed, which is robust against the base line variations and included pile up rejection. The algorithm is tested and demonstrated with a set of mixed heater + alpha particle pulses.

The resolution of a bolometer has contributions from – i) intrinsic thermodynamic fluctuation noise (which is expected to be very small and depends on base temperature), ii) electronic noise (can depend on sensor resistance and can be temperature dependent), iii) vibration noise (will be important at lower temperature). To assess the impact of different noise components, the resolution of the bolometer was measured with heater pulses for equivalent energy of $E \sim 0.3$ MeV to 5 MeV, in the temperature range 10-100 mK. At each temperature V-I measurement was done for the sensor and an optimum bias current was chosen for measurements. The standard deviation ($\sigma_e$) and resolution ($\sigma_e/E$) are derived from the pulse height spectra generated using the above mentioned analysis technique. The measured energy resolution at 5 MeV varies from $\sim 0.5 \%$ at 20 mK to 5% at 100 mK. For a given temperature, the $\sigma_e$ is found to be independent of the energy, in the measured range. The $\sigma_e$ measured at 20 mK, namely, $\sim 22 \pm 1$ keV, is comparable to the earlier measurement in the micro-kelvin wet fridge setup.

The readout electronics is an important and challenging aspect of the cryogenic bolometer. Presently, the neutron transmutation doped (NTD) Ge sensor is kept at $\sim 10$ mK, and is connected to a commercial differential low noise amplifier, which is kept at room temperature. The amplifier is a low frequency differential amplifier (FEMTO DLPVA-100-F) which provides a variable voltage gain upto 80 dB with an input voltage noise density $\sim 5.5 nV/\sqrt{Hz}$. An initiative has been taken for indigenous development of a cryogenic amplifier with improved noise performance. It is planned to mount the preamplifier at the 40K station of the CFDR, which will help to reduce the noise from the amplifier and the RC time constant of the detector, thus making the detector response faster.

For the first pre-amplification stage at cryogenic temperature, a low noise differential amplifier has been designed and simulated in Advanced Design System (ADS) from Agilent. The amplifier consists of common drain amplifier with an active source resistance to achieve a voltage gain close to unity. The second stage of the preamplifier is a differential amplifier stage. A voltage gain of 20 dB with an input voltage noise density $\sim 1.5 nV/\sqrt{Hz}$ is obtained in the simulation. The noise performance of the amplifier is also simulated with different values of sensor resistance in the range of 20 k$\Omega - 2$ G$\Omega$. It is found that there is little effect of sensor resistance upto 200 k$\Omega$ on the input voltage noise density of the amplifier. As the sensor resistance increases above 200 k$\Omega$, the effect of input current noise density of the amplifier comes into play and increases the effective input voltage noise density of the amplifier. Fabrication and testing of amplifier is in progress.
The isotopic composition of detector grade germanium sample was measured using Secondary Ion Mass Spectroscopy (SIMS) technique at BARC to estimate the net carrier concentration after the irradiation. The samples are confirmed to be of high purity and with $^{74}$Ge concentration marginally higher than that of $^{76}$Ge. To assess the surface impurities, if any, SIMS was also done on the sample after removing a 50 micron layer by chemical etching. As expected, no significant surface impurities were observed since wafers are unpolished on either side.

The improvements to NTD Ge fabrication technique is an ongoing process. The wrap around electrical contacts, implemented for uniform electrical field, have shown better reproducibility. It should be mentioned that the contribution from the specific heat of the NTD sensor is expected to be negligibly small as compared to that of the bolometer. Hence, the efforts towards fabrication of smaller size sensor have been initiated. Fabrication of a batch (~10 no.s) of ~3 mm x 3 mm x 1mm sensors is in progress. A Westbond make (7KE) wirebonder machine has been installed and is used for making electrical connection to NTD Ge sensors and silicon heaters with gold wire bonds.

It is known that tin has an allotropic phase transition from a metallic $\beta$ phase to a semiconducting $\alpha$ phase on cooling below 13°C. This transition can affect the longevity and performance of the tin bolometers and is a major concern for TIN.TIN. It is known that alloying with certain elements (e.g., Pb, Bi etc.), with a few % concentration, inhibits the transformation. Therefore, crystals of SnPb, SnBi and SnCd alloys were synthesized for this purpose. The SnCu crystal, which is known to be susceptible to $\beta-\alpha$ transformation, was synthesized as a control sample. The compositions of all the crystals were measured using Wavelength Dispersive X-Ray Fluorescence (WD-XRF) as well as Energy Dispersive Spectroscopy (EDS).

Seeded cooling tests were performed on the samples to check the stability against the phase transition. Scanning Electron Microscope (SEM) images were recorded before and after incubation with seed (at ~40°C for a period of 5 days). The SnBi and SnPb samples were found to be the most resistant to the transformation. From radio purity considerations, the concentration of Pb and Bi needs to be reduced. This is also essential from detector performance point of view, such that the superconducting property of the alloy should not differ greatly from that of pure tin. Further studies on alloying and characterization of alloys are in progress.

For rare decay studies, background reduction is of paramount importance and neutron background is a major concern, since it is difficult to suppress. The neutron background originates from spontaneous fission of U/Th isotopes and cosmic muon induced reactions. Usually high Z materials are used for gamma shielding and can become a source of neutrons. Hence a graded gamma/neutron shield needs to be designed for a detector. In addition, simulations of low energy neutrons do not show very good agreement with measurements. Hence, experimental studies for neutron production and absorption are essential for neutron shield design, including choice of material. With this motivation, absorption of fast and thermal neutrons in various absorbers such as high density polyethylene (HDPE) and rubber with various concentrations of Boron were studied. Measurements were carried out with standard neutron sources as well as using $^8\text{Be}(p,n)^9\text{B}$ reaction with proton beam from the Pelletron at E = 18 MeV. A major concern with the borated rubber is presence of Zn and S trace elements that lead to enhanced gamma background, which is undesirable. Further, to benchmark the neutron transport/absorption simulations, the fast neutron irradiation with different target (Al, Au, Ni, Fe) – absorber (HDPE/borated rubber of diff. thickness) combinations materials were carried out. The irradiated targets were counted off-line and production yields are estimated from the yields of characteristic $\gamma$-rays. Data is compared with calculated values using simulations of neutrons and known reaction cross-section through different absorbers. Data analysis is in progress. The neutron irradiation studies are also used for trace impurity assessment of detector and surrounding materials. It was found that low background Pb ($^{208}\text{Pb}$ < 0.3Bq/kg) shows Al traces and is of concern.

Thermal neutron capture in $^{124}\text{Sn}$ is also of significant concern and needs to be investigated. For this purpose, enriched $^{124}\text{Sn}$ targets were irradiated with thermal neutrons in DHRUVA reactor at BARC in two separate experiments- one minute irradiation (total flux ~ 3 x $10^{15}$ n/cm²) for short lived impurities and 14 days irradiation (total flux ~ 1.5 x $10^{20}$ n/cm²) to study the background arising from $^{126}\text{Sn}$. While no additional impurities were observed in the enriched sample, several high energy gamma rays resulting from...
$^{124}\text{Sn}(n,\gamma)^{125}\text{Sn}\rightarrow^{125}\text{Sb}$ ($T_{1/2} \sim 10 \text{ min}, 10 \text{ days}$) were observed. This emphasizes the need for underground storage of the detector material. The long irradiation was carried out to study the formation of long lived isotope $^{120}\text{Sn}(T_{1/2}\sim 2 \times 10^3 \text{ years})$ via sequential 2-neutron capture in $^{124}\text{Sn}$. The $^{120}\text{Sn}\rightarrow^{120}\text{Sb}\rightarrow^{120}\text{Te}$ ($Q\sim 3673$ keV), can significantly affect the background in region of interest of NDBD of $^{124}\text{Sn}$ ($\sim 2.2$ MeV). However, since sequential 2-n capture is substantially weaker than $(n,\gamma)$, it is challenging to measure the weak decay branch of $^{120}\text{Sn}$ in the presence of strong $^{120}\text{Sb}$. To enhance the sensitivity, coincidence measurements are carried out in the INGA setup and data analysis is in progress.

The cosmic muon induced $(n,n'\gamma)$ reactions are being studied in TiLES. In addition, as separate setup MINT (Muon Induced Neutron detection at TIFR) has been designed. This consists of an efficient thermal neutron detector CLYC inside $\sim 10$ cm thick HDPE box (which acts as a moderator) surrounded by Pb together with plastic scintillator for muon detection. The thickness of Pb and HDPE were optimized using simulations and measurements. The CLYC($\text{CsI}(\text{Li})\text{YCl}_3$) detector, detects thermal neutrons via $^4\text{Li}(n,\alpha)^3\text{H}$ reaction. The distinct peak at 3.2 MeVee gives a clear identification of the neutron events. Detailed studies for characterization and optimization of CLYC using pulse shape discrimination were carried out. The CAEN digitizer based DAQ has been setup and analysis programs are developed on the ROOT platform.

A portable low background counting setup with an annular anticompton shield surrounding cryocooled HPGe detector (30%) is being developed. The characterization of the detector and simulations for developing effective model are in process. [Abhijit Garai, H. Krishnamoorthy, Aparajita Mazumdar, G. Gupta, Ashif Reza, V. Nanal, R.G. Pillay, S. Ramakrishnan, V.M. Datar, M.S. Pose, S. Mallikarjunacharya; A. Shrivastava, (NPD, BARC), K.C. Jagadeesan, S.V. Thakare (IP&AD, BARC)]

**DBD in $^{94}\text{Zr}$**

In continuation of study of DBD in $^{94}\text{Zr}$, the half-life of the double beta decay transition of $^{94}\text{Zr}$ into the first excited state of $^{94}\text{Mo}$ has been investigated with a low background gamma spectroscopy setup at the Felsenkeller underground laboratory in Dresden, Germany. No signal has been observed and a new best lower half-life limit is set at $5.2 \times 10^{19}$ yr (90% CI). This is a 50% improvement compared to our earlier measurement in the previous year. The improvement could be achieved with a 6 times lower exposure compared to the previous best limit of our measurement in TIFR, due to a detector setup with significant lower background. [N. Dokania, D. Degering, B. Lehnert, V. Nanal, K. Zuber]

**R&D related to PARIS**

For study of high energy $\gamma$-rays in reactions involving low intensity radioactive ion beams (RIB), a high efficiency detector array PARIS (Photon Array for the Studies with Radioactive Ion and Stable beams) is being developed. The PARIS array is based on the concept of phoswich detector, where a $\text{LaBr}_3(\text{Ce})$ crystal is optically coupled to a NaI(Tl) crystal and both detectors are read out by a single PMT. The phoswich detector design was developed by Saint-Gobain Crystals. Recently, CeBr$_3$ detectors are also shown to be comparable to $\text{LaBr}_3(\text{Ce})$ detector, in terms of energy and time resolution. With this motivation, the PARIS collaboration has also explored the CeBr$_3$-NaI(Tl) phoswich detector configuration. We have carried out a detailed characterization of a CeBr$_3$-NaI(Tl) phoswich detector. On the average, the resolution of CeBr$_3$ ($\sim 5\%$ at 662 keV) is only slightly worse than that of LaBr$_3$ ($\sim 4.5\%$ at 662 keV). In high energy experiments, where the recoil velocity is large and results in significant Doppler broadening, this difference in the intrinsic resolution may not be significant. Moreover, CeBr$_3$ being free of internal activity, has lower background. Thus, CeBr$_3$-NaI(Tl) phoswich detector is shown to be a viable option for the PARIS array. The digital DAQ test bench based on CAEN digitizer has been set up. The PARIS detectors, with high light output, need a special voltage divider for better linearity over a wide energy range. The PCB for the voltage divider has been designed as per the collaboration specifications and assembly is in process. Tests for combining the PARIS detectors with INGA for specific experiments have been initiated. [Chandan Ghosh, B. Dey, G. Gupta, V. Nanal, R.G. Pillay, M.S. Pose]
The low energy electron molecule collision and particularly the transient negative ion formed after capture of such electron plays crucial role in various phenomena starting from astrochemistry to radiation biology. There are several groups worldwide, trying to understand the dynamics of these negative ions. In this context, our group has discovered the functional group dependent site selectivity in the dissociation of these transient negative ions, which can potentially be exploited for chemical control using electrons. Based on this theme, we have investigated many simple aliphatic organic molecules in the past and shown a simple well defined pattern in their dissociation dynamics. Now we have extended these efforts to the aromatic compounds, which are also little bigger than what we have studied so far. We have unravelled the role of delocalised electron cloud, which is at the core of aromaticity of these compounds in the observed functional group dependent site selectivity in dissociation.

Pyridine and pyrimidine

Almost a decade ago we have demonstrated the bond selectivity in dissociative electron attachment that stems from the functional group dependence in the anion resonance states. These resonances are highly localised in the organic molecules at the dissociating bonds. For example, the amine group’s selectivity in N-H bond break at a specific electron energy was found to be from the core excited resonance that is associated with the excitation of the lone pair of the nitrogen atom and subsequent capture of incoming electron. In order to investigate this functional group dependence in dissociative electron attachment, which is crucial for control of electron induced chemistry, for the aromatic compounds we investigated the DEA dynamics for pyridine (C6H5N) and pyrimidine (C6H4N2). Besides, these simple aromatic compounds are the simplest precursor versions of more complicated biologically important molecules like DNA and RNA bases. The aim of these studies was to systematically investigate the site selectivity with regards to N-atom in these molecules and the effect of delocalized electrons in the aromatic ring on it. In the pyridine measurements, we found H- and CN- channels with the H- angular distribution, kinetic energy distribution as well as absolute cross section matching with that from the benzene. This is expected as the lone pair of electrons from the N atom do not mix with the delocalised π-electrons and hence the two molecules would respond identically to the incoming free electron. In the CN-channel the observed kinetic energy is up to 1 eV with the angular distribution isotropic indicating multiple body break up mechanism at work. In the case of pyrimidine no H- ions were observed which was a big surprise. We are still investigating this. The other ion observed in the process is CN- which peaks at 5.4 eV and 9 eV. Here too the CN- shows isotropic distribution with kinetic energy as high as 2 eV. [Vishvesh Tadsare, Vaibhav S. Prabhudesai and E. Krishnakumar]

Aniline and benzyl amine

Taking this theme of site selectivity in aromatic compounds further, we carried out the DEA measurements on aniline and benzyl amine. The aniline measurements show H- signal peaking at 5 eV, 9 eV and 10.5eV. The partially deuterated aniline (C6D5NH2) showed the D- signal only at the 9 eV peak whereas that peak is found to be absent in H- channel. This indicates that 5 eV and 10 eV features are arising from the H atom on the N-H site. This is consistent with our understanding of the site selectivity. However, the angular distribution at 5 eV showed significant deviation from that for NH3. This is indicative of different dynamics at play but leading to the site selectivity. In the earlier work on photodissociation of aniline, the N-H dissociation at 4.6 eV is found to be originating from the excitation from the delocalized pi electron ring which passes on to the antibonding orbital on the N-H bond. If this same state is the parent state for the resonance contributing to the DEA peak at 5 eV, it implies that although the site selectivity is observed in the aromatic compound the mechanism may be different. The DEA measurements from the benzyl amine showed a peak in H- signal at 5.5 eV. Angular distribution obtained at that energy showed marked similarity with that from the ammonia. This clearly shows that the effect of delocalized pi electrons from the phenyl ring on the lone pair excitation on the N atom is reduced as the NH2 group is moved away from the ring. The behaviour of the benzyl amine is found to be similar to that from n-propylamine. Further analysis is going on. [Vishvesh Tadsare, E. Krishnakumar and Vaibhav S. Prabhudesai]
Pyrole and n-methyl pyrrole

As seen in the case of pyridine, the presence of N atom in the benzene ring does not make any difference in the DEA pattern in the H- channel. This is mainly because the lone pair of electrons from the N atom does not participate in the delocalized pi electron cloud. Pyrrole is a molecule with 5 member carbon with one atom being N atom. Here the lone pair of electrons from N atom contributes 2 electrons to the pi ring making it a six-member chain. As expected the DEA to pyrrole showed H- signal peaking at 5.5 and 9 eV electron energy. The 5.5 eV peak shows angular distribution similar to that from the ammonia. The same peak is found to be absent in DEA to n-methyl pyrrole as the corresponding H atom from the N-H site is replaced by a methyl group confirming the origin of this peak from the N-H site. However, the 9 eV peak shows substantially different angular and KE distribution. This is found to be same in both the pyrrole and its methylated version. From the n-methyl pyrrole additional structure of low energy H- channel peaking at 10 eV is also found which is consistent with the presence of the CH3 group. The quantum chemistry-based calculations of the excited states of the anions of these molecules are being carried out by our collaborators. [Samata Gokhale, E. Krishnakumar, Vaibhav S. Prabhudesai]

Nuclear Structure and Dynamics

Nuclear structure near closed shell

Spectroscopy of the high spin states of nuclei near closed shell remain a subject of interest of our group to study the predictions of shell model calculation based on effective interactions as well as emergence of collectivity at high spin. Fusion evaporation reactions have been mostly used for these investigations. However, for the study of high spin states of some of the nuclei near 68Ni and 132Sn, we have used multi-nucleon transfer reaction and fusion/transfer induced fission process, respectively. One of the highlights of this project is the observation of a regular band in 89Zr extending the level scheme up to 49/2 hbar. The Directional Correlation of oriented states, polarization and lifetime measurements of the cascade of gammarays forming the dipole band of 89Zr have been carried out using the INGA set-up. The cranked Nilsson Strutinsky model is used to describe the rotational band which suggests the nucleus is triaxial at high spin and rotates around the longest axis. During 2017, we have performed an experiment aimed at studying medium and high spin states in 90Zr using 13C+82Se reaction at 60 MeV beam energy. The data analysis of this experiment is in progress. The motivation of the experiment was to study the emergence of collectivity at high spin in 90Zr, one of the classic spherical nuclei. The Cranked Nilsson Strutinsky (CNS) calculation for 90Zr suggests emergence of deformed shapes around I ~ 30 hbar due to occupation of high-j orbitals. This measurement will shed light on the path of shape evolution towards the Jacobi shape transition predicted in 90Zr. In addition, this investigation will provide information on the role of the high-j orbitals, e.g., νh11/2, in this region, which are responsible for the shape evolution of neutron rich Zr isotopes. Experimentally, study of high spin states of isotopes near 90Zr beyond 25 hbar with large detector array remains an experimental challenge. From a number of heavy ion induced fusion reactions used to study nuclei near 90Zr, most of the cases the nucleus does not develop well deformed band structure even at high excitation energy even if the expected angular momentum imparted is 40 - 60 hbar as per the chosen reaction. We plan to use 48Ti + 50Ti reaction around 200 MeV in future for the present study. The proposed reaction has the possibility of the emission of a correlated pair of α particles from the compound nucleus. This may favour the population of deformed states at high spin in 90Zr. [R. Palit, Md. S. R. Laskar, C. S. Palshetkar, F. S. Babra, S. Biswas, S. Jadhav, R. Donthi, B.S. Naidu, A. Thomas]

Production of neutron rich nuclei by Incomplete Fusion reaction

With 5 MeV/A beam energy the incomplete fusion cross sections are 10 to 100 mb. In such reactions, a part of the projectile gets fused to the target and the other part moves in the forward direction with velocity of the projectile. With beams of 7 Li, 9 Be and 11B one can effectively get fusion of neutron rich nuclei like 3 H, 5 He and 6 He with stable targets. This method though known for sometime is not yet explored to its full potential. This reaction is very useful to produce relatively neutron rich nuclei than that of fusion evaporation reaction. The complete and incomplete fusion cross-sections for 7 Li+124Sn reaction were
measured from the online and offline characteristic gamma ray detection techniques. We plan to measure the spin population in incomplete fusion reactions along with the charge particle emissions. This will be helpful in optimization for channel identification and spectroscopy of relatively neutron rich nuclei. There is a distinct feature in individual incomplete fusion cross-sections, i.e., t-capture is much more dominant than alpha-capture at all the measured energies. Applications of this method to spectroscopy of neutron rich translead nuclei will be helpful for the study of high-spin isomers, residual interactions and developments of octupole collectivity. This method has been used to study the neutron rich 111Ag isotope to study the evolution of triaxial shapes in A ~110 region. The experiment has been carried out at TIFR with INGA coupled to CsI(Tl) detectors using 7 Li+110Pd reaction. [R. Palit, C.S. Palshetkar, Md. S. R. Laskar, F.S. Babra, S. Biswas, S. Jadhav, R. Donthi, B.S. Naidu, A. Thomas, V. Parkar (BARC)]

Structure of high spin Isomers in nuclei near N=82 and g-factor measurements

The nuclei around N=82 shell closure are interesting laboratory for studying various nuclear structure phenomena due to the possibility of triaxial and spherical shapes at low and medium spins. For the A~135 nuclei with neutron number close to N=82, experimental information on high-spin states is scarce due to limited number of projectile-target combinations available. Presence of isomers as well as non-stretched transitions in the level scheme for these nuclei causes additional experimental constraints. Recently, detailed spectroscopic studies of 133,134,135,136La isotopes have been carried out which reported existence of various phenomena like magnetic rotation, chiral rotation, spin isomers and shape isomers. The structures of these high-spin isomers in some of these nuclei have been discussed with multi-quasi-particle configurations. The configurations of these isomers play a decisive role in the assignment of the configurations of higher exited bands decaying through these isomers. Though the multi-quasiparticle structures of these isomers are easier to interpret, their unique identification is possible from the measured static magnetic moment measurements. Therefore, the g-factor measurements are extremely useful for these isotopes for improving the quality of information for the level structures and understanding of the dynamics of various exotic modes mentioned above. In our recent work, time differential perturbed angular distribution (TDPAD) technique was used for the measurement of the g-factor of the 2738 keV isomer in 135La. The measured g-factor needs to be compared with the results of the model calculations to assign the configuration of the isomer. [Md. S. R. Laskar, R. Palit, S.N. Mishra, S. Saha, S. Biswas, P. Singh, F. Babra, S. Mahanto]

Complete and incomplete fusion cross sections for 7 Li+124Sn reaction

The complete and incomplete fusion cross sections for the 7 Li+124Sn reaction were measured using online and offline characteristic γ-ray detection techniques. The complete fusion (CF) cross sections at energies above the Coulomb barrier were found to be suppressed by ~26% compared to the coupled channel calculations. This suppression observed in complete fusion cross sections is found to be commensurate with the measured total incomplete fusion (ICF) cross sections. There is a distinct feature observed in the ICF cross sections, i.e., t capture is found to be dominant compared to α capture at all the measured energies. A simultaneous explanation of complete, incomplete, and total fusion (TF) data was also obtained from the calculations based on the continuum discretized coupled channel method with short range imaginary potentials. The cross section ratios of CF/TF and ICF/TF obtained from the data as well as the calculations showed the dominance of ICF at below-barrier energies and CF at above-barrier energies. [V. V. Parkar, Sushil K. Sharma, R. Palit, S. Upadhyaya, A. Shrivastava, S. K. Pandit, K. Mahata, V. Jha, S. Santra, K. Ramachandran, T. N. Nag (BARC), P. K. Rath (Manipal Univ), Bhushan Kanagalekar (Rani Channamma University), and T. Trivedi (Guru Ghasidas Vishwavidyalaya)]

Development of Ancillary systems for INGA and its DSP based data acquisition system

A highly segmented 4p1i-charged particle detector array (CPDA) is being fabricated and will be coupled with the INGA facility. It will consist of 80 CsI(Tl) crystals coupled to PIN diodes. The mechanical structure of the array has been designed and fabricated at TIFR. The particle identification has been carried out using DSP techniques at TIFR. Owing to the low amplitude of the preamplifier signals, DSP was found to be challenging. Different algorithms have been developed to optimize the on-line identification of the light charged particles.
The commissioning run of the CPDA with 24 CsI(Tl) detectors with clover detectors has been completed. A Root based analysis code has been developed for the study of particle gated gamma spectra. This will improve the overall sensitivity of the spectrometer. An array consisting of 16 LaBr3(Ce) detectors has been designed which will be coupled to the INGA. Test experiments with 8 such detectors with the Clover array has been performed with the 250 MHz digitizer boards. [R. Palit, Md. S. R. Laskar, C.S. Palshetkar, F.S. Babra, S. Biswas, S. Jadhav, R. Donthi, B.S. Naidu, A. Thomas]

DEGAS set-up for DESPEC experiment at FAIR

The DESPEC Germanium Array Spectrometer (DEGAS) is a high-purity germanium gammadetector array for high-resolution spectroscopy of electromagnetic decays from exotic nuclear species. It is a key instrument of the Decay Spectroscopy (DESPEC) experiment at FAIR. At DESPEC rare isotopes produced by the Super-FRS will be stopped in an active implanter (AIDA) surrounded by DEGAS measuring gamma-rays from alpha, beta, proton, neutron and isomeric decays. The preamplifiers for the HPGe detectors require, besides the traditional good energy and timing properties, also fast and clean transfer functions to register unperturbed signal traces for pulse shape analysis. Input stage FETs are supposed to be operated cold. Fast reset in case of detector overload due to energetic particle hits is required. The design and development of a prototype for the preamplifier have been carried out at TIFR in collaboration with GSI. Various mechanical parts of the prototype of the cryostat and the housing of BGO back-catcher of the DEGAS for phase-I have also been fabricated at the TIFR central workshop. The specified tolerances of the dimensions of the various components have been checked with the coordinate measuring machine (CMM) in the TIFR central workshop. The vacuum test of the prototype of the cryostat has been carried out in our detector laboratory. [R. Palit, R. Donthi, B.S. Naidu, S. Jadhav, A. Thomas, Y.K. Arora, R.D. Chogale, S. Sinha, J. Gerl, I. Kojouharov (GSI)]

Study of Evaporation Residue gated spin distributions for the $^{224}$Th compound nucleus

A major experiment was carried out during this period using the HYRA magnetic recoil separator and the TIFR $4\pi$ spin-spectrometer. The primary objective was to investigate the survival probability of heavy nuclei against fission and the role of nuclear viscosity. This is best achieved by measuring the evaporation residues (ERs) from narrow domains of angular momentum. The $^{224}$Th compound nucleus was populated using two different reactions, namely, $^{16}$O on $^{208}$Pb and $^{18}$O on $^{208}$Pb, at different projectile energies ranging from 85 to 122 MeV. The evaporation residues were detected at the focal plane of the HYRA spectrometer. The low energy gamma rays emitted from the ER were detected using the TIFR $4\pi$ spin-spectrometer surrounding the target position. The transmission efficiency of the HYRA spectrometer was used to extract the ER cross sections. The full response matrix of the $4\pi$ spin-spectrometer was used to extract the angular momentum (spin) distribution of the compound nucleus. The response function of the spin-spectrometer was convoluted with chosen spin distributions to reproduce the experimentally obtained gamma-fold distributions. The most probable values of the spin distributions were found to increase with the beam energy. This was the first ever measurement of angular momentum gated ER cross sections for both the reactions. The ER cross sections from both the reactions were found to be very similar within experimental errors and do not show any dependence on the difference in the two target-projectile combination. Detailed statistical model calculations and dynamical calculations within Langevin formalism have been carried out to reproduce the data. It has been shown that standard statistical model without dynamical effects of viscosity fail to reproduce the data. [I. Mazumdar, IUAC, Karnataka Univ., VECC, UGC-DAE-CSR, Andhra Univ., Univ. of Calicut, Univ. of Kerala]

Fusion excitation function and back angle quasi-elastic scattering studies

Fusion evaporation residue cross sections and 180 degree back scattering cross sections were measured using the Heavy Ion Recoil Analyser (HIRA) at IUAC for the $^{12,13}$C+$^{197}$Au systems. This was the first measurement of back scattering and also fusion-evaporation for the $^{13}$C+$^{197}$Au system. The primary motive was to study survival against fission as one approached N=126 shell closure while keeping the number of protons unchanged. The $^{197}$Au recoils following 180 degree back scattering of the projectiles ($^{12,13}$C) and move forward around zero degree with the beam through the mass separator HIRA. The beam particles were efficiently rejected by HIRA and the
recoils were carried to the focal plane and detected in a large area position sensitive Multi-Wire Proportional Chamber (MWPC). Two silicon surface barrier detectors were used in the target chamber to measure the Rutherford scattered beam particles for absolute normalization of the ER cross sections. Another silicon surface barrier detector was placed at 161 degree back angle to measure the back scattered particles. [Collaborative work with UGC-DAE-CSR, Kolkata and IUAC, New Delhi.]

**Optical Model analysis of $^{12}$C($p,p',\gamma$)$^{12}$C reaction**

We have completed detailed analysis of inelastic scattering cross sections and angular distribution of gamma-rays from the $^{12}$C($p,p',\gamma$)$^{12}$C reaction for four excited states of the $^{12}$C nucleus for beam energies ranging from 8 to 22 MeV. The analysis has been carried out within the framework of Optical Model formalism using realistic nucleon-nucleon potential constructed by us from existing data. We have carried out coupled channel calculations considering coupling of the excited states of $^{12}$C nuclei in our model calculations. It has been shown that coupling of the states is essential to reproduce the data. The role of the Hoyle state of $^{12}$C is found to be significant in reproducing the data for the first excited state at 4.43 MeV. This is the first work to study differential cross section and angular distribution of gamma-rays from first four excited states of $^{12}$C. [I. Mazumdar, M. Dhibar (IIT-Roorkee), S. P. Weppner (Eckerd College, Fl.)]

**Studies with CeBr$_3$ scintillation detector**

The CeBr$_3$ crystals are latest additions in the list of advanced scintillation detectors. We have carried out complete characterization of a small size CeBr$_3$ crystal during this period. The measurements included, energy and timing resolutions and their dependence on energy, linearity of response, absolute photo-peak detection efficiency and its dependence on energy. We have also carried out realistic Monte Carlo simulations using GEANT4 package to reproduce the experimental gamma-ray spectra and detector responses. In-depth measurement of internal activity of the CeBr$_3$ has been done and compared with the internal activity of LaBr$_3$ :Ce detector. [I. Mazumdar, Y. M. Sharma, S.M. Patel, R. Sariyal (Panjab Univ.), V. Ranga, (IIT-Roorkee)]

**Role of F -spin multiplets in identical band phenomena in normal deformed nuclei**

We have carried out a systematic study of F -spin multiplets having similar product of their valence nucleons (i.e., Np Nn -values) to extract the prominent features which are responsible in generating the identical rotational bands among them. It has been established from the experimental data of rare-earth region that a subsequent addition of proton pair in an isotonic set of nuclei increases their (i.e., isotones) pairing contribution whereas a reversing trend has been seen while adding a neutron pair in an isotopic set. Similar type of opposite trends have also been observed in their quadrupole deformations while adding a pair of proton and neutron, respectively, in an isotope and isotope. Thus, a simultaneous addition of both proton and a neutron pair in any one of the F -spin multiplets does not alter the pairing contribution as well as deformation structure of a newly emerging multiplet and hence the identicity prevails between their rotational spectra. These experimentally observed opposing trends of pairing correlations and deformation parameters with the addition of a particular nucleon pair in an isotope and isotope, respectively, are also supported by our cranking model calculations. These systematic studies together with the cranking model calculations have further been extended to explore the possibilities of obtaining the identical band structures between odd-A and neighboring even-even nuclei. [I. Mazumdar, S. S. Malik (GNDU University, Amritsar)]

**Role of quantum phase transition in spontaneous fission**

A systematic study of quantum phase (i.e., nuclear shape) transition have been carried out from the standpoint of spontaneous fission. The quantum phase transition is mainly defined by the ratio of relative excitation energies of $I^+ =4^+$ to $I^+ =2^+$ states between heavier and lighter fission fragments and its extremum value fixes the most probable pair of fission fragments. This ratio provides an effective order parameter which is not only easy to measure, but also distinguishes between first and second order phase transitions and takes on a special value in the critical region. Once the fission fragment pair is decided, its preference is governed by F -spin selection rule that is based on baryon number conservation. It implies that if a pair of conjugate fission fragments together with appropriate neutron emission have total F -spin equal to 1/2 with
with projections $F_{\mu} = \pm 1/2$ then and only then the fission proceeds, provided both the valence shell nucleons in either of the fission fragments are treated as particles like and is valid for the even-even decay modes. The goodness of $F$-spin selection rule extends further to extract all the allowed pairs of neutron-rich fission fragments. The validity of $F$-spin selection rule has been tested in various decay modes of spontaneous fission and seems to be a milestone in deciding the appropriate decay channels. These findings have important consequences in the formation and discovery of drip-line exotic nuclei. [I. Mazumdar, S. S. Malik (GNDU Univ. Amritsar), S.R. Jain (BARC)]

Theoretical study of rare shape transitions in hot and rotating $^{188}$Os nucleus

The nucleus is a finite quantum many-body system. The increase in the temperature (T) and angular momentum (l) will leads to a variety of nuclear shape transitions. The temperature at which the shape transitions occur is known as critical temperature. We have studied nuclear shape transitions in hot and rotating $^{188}$Os nucleus with increasing T and I. Our studies show that these nuclei show a signature of rare shape transition from non-collective oblate to non-collective prolate at certain critical temperatures. We have employed the microscopic-macroscopic approach to calculate the free energy surfaces (FES) of $^{188}$Os nucleus at different combinations of T and I. The liquid drop model energy has been calculated considering a triaxially deformed nucleus and the shell corrections have been obtained with exact temperature and spin dependence. We have concluded that at certain temperature, $^{188}$Os nucleus shows a rare shape transition from oblate shape rotating about its symmetry axis to prolate shape rotating about its symmetry axis with increase in the angular momentum values. [I. Mazumdar, A. K. Rhine Kumar (Cochin Univ. of Science & Technology), P. Arumugam (IIT-Roorkee)]

Accelerator based Atomic Physics

Collision-induced Fragmentation studies of atomic and molecular systems with highly charged ions (HCl) as a probe

State-selective capture studies with Ar$^{8+}$-He interactions

State-measured electron capture cross sections are measured for collisions of 240 keV of Ar$^{8+}$ ions with cold He target. The parameters that have been probed during these state-selective capture studies are: The Q-value for a reaction is directly related to the longitudinal momentum transfer to the recoil ion and the velocity of the projectile ion. This ‘Q’ refers to the electronic energy released/absorbed in the capture process, which is the difference between the binding energy of the final state of the Ar$^{+}$ (n, l) ion and the ionization potential of He in ground state, nearly 24.59 eV. With this direct measurement of the parallel momentum using COLTRIMS setup, one will get unprecedented information about the final-state population of the projectile ions and scattering angle gives details of impact-parameter. From our experiments on He with Ar$^{8+}$ (240 keV) as probe, we found that the momentum resolution measured is close to 0.28 a.u., which is in good agreement with earlier reports.

Two-center interference effect in N$_2$ during collisions with Ar$^{8+}$

State-selective electron capture experiments with N$_2$ as target and Ar$^{8+}$ (80 keV, 160 keV and 240 keV) as projectile, respectively, has been carried out. Within the framework of molecular-axis orientation dependent transfer-excitation measurements, we tried to look at the two-center Young’s double-slit type quantum interference effects in N$_2$. The single-capture coincidence measurements show an oscillatory behaviour in angular distributions. With the help of published binding energies and present work, we confirm that the signature seen is from the interference effects occurred due to the involvement of electrons from the outer-valence states of target.

Probing Cis-Trans isomeric nature in H$_2$O$_2$

We have carried out ion-impact induced dissociation studies of hydrogen peroxide (H$_2$O$_2$) with earlier RIMS setup. In this work, 1 MeV Ar$^{8+}$ ions that are obtained from the electron cyclotron resonance ion accelerator (ECRIA) at TIFR, Mumbai, has been used a projectile beam. During the post-experiment analysis, the following different dissociation channels has been identified from the measured fragment ions TOF-TOF coincidence mapping. Corresponding to all these
dissociation pathways, kinetic energy (KE) of the individual fragments, total kinetic-energy release (TKER) and angular distributions has been obtained from the measured momenta of coincidently-detected fragment ions. It is also identified as the smallest chiral molecule that exists today with additional geometries like cis- and trans-H$_2$O$_2$. To the best of our knowledge, the signature of cis- and trans-H$_2$O$_2$ has been discovered in the present work will be the first of its kind experimentally. We have three-body Dalitz plots to identified this nature. Further to analyze these structures in detail, a four-body fragmentation dynamics has been employed.

**Gas Mixing effect at the ECRIA**

Gas mixing effect in the electron cyclotron resonance ion source (ECRIS) is a well-known technique for increasing the currents of highly charged ions (HCI). Mixing a lighter (or heavier) gas with the main gas significantly increases the output currents of HCIs of the main gas. Xenon and krypton are taken as the main gases. They are mixed with different support gases H$_2$, He, Ne, O$_2$, Ar, CH$_4$ and CO$_2$ at different ratios. Better enhancements of the higher charge-state currents are observed in case of mixing with molecular gases such as N$_2$, O$_2$ and CO$_2$. Therefore, molecular dynamics in such plasma may be considered while modelling the enhancement of HCIs yields by mixing gas technique.

**M X-ray production from high-Z elements upon proton impact**

The line resolved ($\sigma_{Mk}$, k=ζ, ζβ, γ, m1) and the total M-shell X-ray production cross-sections of Au, Bi, Yb, Tl and Pb induced by low energy proton beams are measured. The experiments are performed at the TIFR-ECRIA facility. The projectile energy dependence (50–300 keV) of the cross-sections are studied. The values are compared with those calculated using theoretical models such as PWBA and ECPSSR. The ECPSSR model tends to underestimate the M sub-shell XRP cross-sections at lower projectile energies. The PWBA model provides a better agreement with the experimental values for projectile energies above 100 keV but gradually overestimates the cross-section with decreasing projectile energies. The intensity ratios $I_{Mk}/I_{M_{total}}$ (k = ζ, ζβ, γ, m1) are found to be in agreement, in general, with the ECPSSR and the PWBA values.

**Emission of electrons from 5-Iodouracil upon fast ion impact**

Electron spectroscopy studies on 5-Iodouracil upon fast ion impact are performed. 5-Iodouracil (C$_4$H$_7$IN$_2$O$_2$) is very similar to thymine (C$_6$H$_6$N$_2$O$_2$), a DNA base. 5-Iodouracil is obtained by replacement of the methyl group of thymine by an I atom. It can act as a radiosensitizer after replacement of thymine in the DNA, enhancing the damage to the biological material upon ion impact. The double differential cross-section of electron emission (DDCS) (d$^2$$\sigma$/d$\Omega$ d$E$) induced by bare C ions of energies 42 MeV and 66 MeV are measured in the energy range 6–600 eV and in angular range of 20º–160º at 12 different angles. Similar measurements are performed for CH$_4$ and the data is used for normalization of the 5-Iodouracil DDCS spectra. Single differential cross-sections (d$\sigma$/d$\Omega$, d$\sigma$/d$E$) and total cross-sections are calculated from the DDCS results. Substantial enhancements in the electron emission from 5-Iodouracil is observed over Uracil for both projectile energies.

**Electron capture studies at the ECRIA**

A new setup is assembled, in the 50ºS beamline at the ECRIA facility, to study electron capture from H$_2$O by bare He ions. Subsequently electron capture from biomolecules will be studied. The setup is based on a new gas cell and a charge state deflector (CSD). The gas cell will be pumped differentially without degrading the vacuum conditions in the experimental chamber. The CSD will be used to deflect the ions after the interaction. A Faraday cup and two channel electron multipliers (CEM) will be used to detect the ions after they are deflected by the CSD. This setup is ready for initial testing.

**Experiments using MeV energy C$^{6+}$ beam from Pelletron**

Ion impact ionization studies of RNA nucleobase, uracil and bromouracil (a halouracil) using 66 MeV bare C ions from Pelletron were performed simultaneously. Halouracils are known to act as radiosensitizers and hence are expected to be beneficial for cancer treatment using hadron therapy. The presence of the high-Z element (halogen in the present case) in uracil produces large number of secondary electrons which helps in causing bond breakage of the DNA/RNA strands.
In the present work, we aimed to obtain a quantitative estimate of the amount of enhancement in electron production from bromouracil compared to uracil. The double differential cross section (DDCS) measurements of electron emission from both the targets were performed under the same experimental conditions to avoid any kind of systematic errors. The preliminary analysis have been completed and we expect to compare the present results with state-of-the-art theoretical models like CDW-EIS and CB1 calculations. Similar measurements have also been carried out for 42 MeV bare C ions on uracil.

Electron impact ionization studies

Experiments have been performed for measuring the DDCS of electrons emitted from N₂ in collisions with fast electrons of different energies varying from 2 keV to 8 keV. A systematic study has been performed for the above mentioned collision system. For all the beam energies, secondary electrons having energies from 1 eV to several hundreds of eV have been measured at different emission angles. In case of 2 keV electrons as projectiles, we have also measured the elastically scattered electrons.

Members


Research Scholars
Chandan D. Bagdia, Shamik Bhattacharjee, Kamalesh Jana, Randhir Kumar, Sramana Kundu, Angana Mondal, Sudipta Lodh Roy, Deep Sarkar, Soubhik Sarkar, Moniruzzaman Shaikh, Md Abul Kalam Azad Siddiki, Vishvesh A. Tadsare, Sheroy Tata

Visiting Fellows
M. Balasubrahmaniyam, V. Rakesh Kumar, N. M. Madugula, Anuvab Mandal, Rana Nandi

Junior / Senior Research Fellows
Madhusree Roy Choudhury, S. D. Gokhale, G. R. Gupta, S. Tendulkar

Administration
Anuya A. Mahambrey

National and International Involvement

E. Krishnakumar
1. Member, Council of Management of DAE-UGC Consortium for Scientific Research
2. Member, International Advisory Committee for Electron-Molecule Symposium
3. Member, International Advisory Board for Journal of Physics B

Sushil Mujumdar
Member of the Optical Society of America

V. Nanal
1. Member of Programme Advisory Committee for Physical Sciences under SERB (DST), 2015-
2. Member, Executive Committee, Indian Physics Association, 2016-
3. Chair, PARIS collaboration steering committee, 2015-

R. Palit
Member, Organizing Committee of DAE-BRNS Symposium on Nuclear Physics, Thapar University Patiala, India, 20 - 24 Dec 2017

Vaibhav S. Prabhudesai
Member, Board of Studies in Physics, Ramnarain Ruia College, Autonomous College under University of Mumbai

G. Ravindrakumar
1. Co-chairman, International Committee on Ultra Intense Lasers (ICUIL)
2. Member, Scientific Advisory Board, “Inertial Fusion
Science and Applications” International Conference (held every two years in Japan, Europe and the USA on rotation)
3. Editorial board member, “High Energy Density Physics (Elsevier)”
4. Editorial board member, “Reviews of Modern Plasma Physics (Springer)”
6. Member, S. Chandrashekhar Prize Committee, AAPPSS- Div Plasma Physics

Lokesh C. Tribedi
1. Member, International advisory committee of conferences (ICPEAC Cairns, Australia, July 2017)
2. Course-director, TIFR-School (SERC) (Feb-2017) on atomic physics
3. Member of the international conference SHIMEC. “Swift Heavy ions in Materials Engineering and Characterization, SHIMEC”, Indore, Oct 2017
4. Member, International advisory committee of the Int.

Visits

Amit D. Lad
1. Vulcan Petawatt Laser, Rutherford Appleton Laboratory, Chilton, Didcot, UK, June 22-24, 2017
2. VEGA Petawatt Laser Facility, Centro de Lasers Pulsados (CLPU), Salamanca, Spain, Feb. 13-15, 2018

Apanjita Mazumdar
Osaka University, Japan (Jan. 2018)

I. Mazumdar
1. Heavy Ion Laboratory, Warsaw
2. Institute of Nuclear Physics, Orsay
3. Indian Institute of Technology, Roorkee
4. Cochin University of Science & Technology
5. Dept. of Physics, Gauhati University
6. Inter University Accelerator Centre, New Delhi

Subhraj Majumdar
1. Karlsruhe Institute of Technology, Karlsruhe, Germany, 15 May -17 May 2017
3. University of Twente, Twente, The Netherlands, 22 May – 23 May 2017
4. IIT Kharagpur, 17th November 2017
5. IIT Kanpur, 4 December 2017
6. ISRO, Trivandrum, 14 December 2017
7. ICTS Bangalore, 18 March – 2 April 2018

V. Nanal
GANIL (France) for collaborative experiment with AGAT+VAMOS+PARIS, “Gamma decay from near threshold states in 14C: a probe of clusterization phenomena in open quantum systems”, July 2017

S. Pal
17th International Conference on Strangeness in Quark Matter, Utrecht, Netherlands, July 10-15, 2017

R. Palit
1. GSI, Darmstadt, Germany, 4 – 11 Jul, 2017
2. 2017 GANIL, Cean, France, 11 – 18 Jul, 2017
3. Osaka University, Osaka, Japan, 8 – 18 Oct, 2017
4. Osaka University, Osaka, Japan, 11 – 29 Dec, 2017

Lokesh C. Tribedi
1. ICPEAC, Cairns, Australia, 25 July-2 Aug 2017
2. ISIAC, Cairns, Australia, 22-25 July 2017
3. CQT, National University of Singapore (NUS), Singapore, Aug 1-4, 2017
4. National Level School TISAAC (TIFR school on advances in Atomic collisions), Convener, March 2017
5. IEMENTech 2017, IEM, Kolkata Science city, May 28-29, 2017
6. Seminar of Recent Trends in atomic and molecular Physics, DDU College-DU, Delhi, 19 Sept 2017
7. ICNIB, International meeting, Indore, October 11-13 (Invited talk, panel discussion, session chair)
8. DST SERC School on Atomic Physics (Electron collisions) RKM, Narendrapur, Kolkata, Dec 4-22, 2018
9. TC-7, ISAMP conference on Atomic Molecular Physics, Tirupati IISER+IIT, January 6-9, 2018 (Invited talk, Chaired 2 sessions)
10. International Conference on Systems and Processes in Physics, Chemistry and Biology ICSPPCB-2018, Assam University, Silchar, March 1-3, 2018 (Invited speaker, member of the Advisory committee)

Invited talks

Abhijit Garai
Effect of vibration on a sapphire bolometer. NSPDI, TIFR, October 2017

Amit D. Lad
1. Intense Laser Produced Magnetic Fields at the Rear Side of Thin Targets. 44th European Physical Society (EPS) Conference on Plasma Physics, at Queen’s University Belfast, Northern Ireland, June 26 – 30 June 2017
2. Catching a Plasma Blow Hot-and-Cold on Ultrafast Time-Scales. ASET Colloquium, Tata Institute of Fundamental Research, Mumbai, September 08, 2017

Aparajita Mazumdar
Cryogenic bolometer development for 0νββ studies in 124Sn. Osaka University, Jan. 2018

I. Mazumdar
1. Study of d(p,γ)3He Reaction Relevant to Big Bang Nucleosynthesis. NuSPRASEN Workshop on Nuclear Reactions, Heavy Ion Laboratory, Warsaw, 22 Jan. 2018
3. Nuclear Fission at Finite Temperature & Angular Momentum: What we know and what we don’t? DAE- BRNS Theme Meeting on New Horizons in Heavy Ion Induced Fission and Nuclear Data Applications, June 22, 2018

Sushil Majumdar
1. Exponentially-tempered Levy sums and Anderson-localized lasing modes in random lasers. Spring School on Tailored Disorder, Karlsruhe Institute of Technology, Karlsruhe, Germany, 15-17 May 2017
4. Spectral fluctuations in materials with structural disorder and high-gain molecular dyes. International Conference on Molecular Spectroscopy (ICMS 2017), Mahatma Gandhi University, Kottayam, 9 December 2017

V. Nanal
1. Search for double beta decay in 94Zr. FIG18, March 2018
2. A Decade of LINAC, NUPLIN, March 2018
3. Exploring the world of nuclei. Panjab University, Chandigarh, March 2018
4. Cryogenic detectors for rare event studies, Present and Future of Nuclear Instrumentation in India. IIT-Ropar, Dec. 2017

R. Palit
1. Rotational Response of Triaxial Nuclei INGA workshop. IUAC, New Delhi, 14 – 15 Sep 2017
2. DEGAS for the study of rare isotopes at FAIR and developing its imaging capability NSPDI. TIFR, Mumbai, 4 – 7 October, 2017
3. Physics highlights of INGA campaign at TIFR and the plan for its upgrade. International workshop CAGRA17, Osaka, 10 – 12 December 2017
4. Perspectives in nuclear physics with modern accelerators and detectors. 87th Annual Session of NASI & Symposium on “Basic Research-Its Role in National Development”, Savitribai Phule Pune University (SPPU), Pune, 8 – 10 Dec 2017

Vaibhav S. Prabhudesai
2. Low energy electron induced chemistry in condensed molecules. Astrochemistry in THz meeting, Chennai, 30-31 October 2017

G. Ravindrakumar
2. Table top plasma gets wind of solar turbulence! TIFR Wednesday Colloquium, Aug 02, 2017
8. Extreme light, extreme states. Chanchal Mazumdar Memorial Lecture 1, IACS Kolkata, Jan 29, 2018
9. Table top plasma gets wind of solar turbulence. Chanchal Mazumdar lecture -2, IACS Kolkata, January 30, 2018

Lokesh C. Tribedi
1. Fast-ion atomic collisions using electron recoil ion X-ray spectroscopy. Seminar-1, Kalyani University, W.B, April 11, 2017; Molecular ionization: probing coherence, collectivity and correlation, Seminar-2, Kalyani University, April 11, 2017
2. Coherence and collectivity in atomic collisions: Fullerenes and biomolecules. CQT-Talk, National University of Singapore, Center for Quantum technology, Aug 3, 2017
3. Accelerator based Molecular ionization: Coherence induced electron interference and collective plasmon excitation. Physics Colloquium: VECC Kolakta, 29 Aug 2017
5. Ion-atom collisions using accelerators and e-interference in molecular double slit. Plenary talk: Seminar on Current trends in AM Physics, DDU College of Delhi University, 19 Sep, 2017
6. Ion-atom collision processes in DNA-base molecules at Bragg peak energy. 4th International conference on nano-structuring by ion-beams DAVV University, Indore, 11-13 Oct 2017
8. Young type electron at molecular double slits using diatomic molecules. ISAMP conference on Atomic Molecular Physics, Tirupati, IISER+IIT, Jan. 6-9, 2018
9. Invited talk, International Conference on. Systems and Processes in Physics, Chemistry and Biology ICSPPCB-2018. Assam University, Silchar, March 1-3, 2018

Conferences Organized by the Department

DST SERC school (3 weeks)
RKM, Narendrapur, Kolkata, Dec 2017 (Part of the DST planning committee and Local organizing committee)

Frontiers in Gamma ray Spectroscopy (FIG2018)
TIFR, 12 – 14 March 2018 (Organiser: R. Pautl)

Workshop on Nuclear Physics at PLF (a decade of LINAC)
TIFR, 15 March 2018 (Organiser: V. Naran)

Non-DAE Research Projects

M. Krishnamurthy
Interaction of size limited matter in intense laser fields, DAE-SRC BRNS project
G. Ravindra Kumar

1. Extreme states of matter created by ultraintense, femtosecond laser pulses, J C Bose fellowship Project, DST, Government of India

2. Triggering and guiding of lighting by plasma filaments induced by high power femtosecond laser, University Grants Commission- Israel Science Foundation (UGC-ISF) project
Cosmology and Astroparticle Physics

X-ray and SZ constraints on the properties of hot CGM

Observations of stacked X-ray luminosity and Sunyaev-Zeldovich (SZ) signal from a cosmological sample of 80,000 and 104,000 massive galaxies was used to constrain the hot Circumgalactic Medium (CGM) density and temperature. The X-ray luminosities constrained the density and hot CGM mass, while the SZ signal helped in breaking the density-temperature degeneracy. A simple power-law density distribution as well as a hydrostatic hot halo model, with the gas assumed to be isothermal in both cases, were considered. It was shown that the mean hot CGM profile goes as $r^{-1.2}$, which is shallower than an NFW profile. The hot CGM was estimated to contain 20 - 30% of galactic baryonic mass within the virial radii, and also broadly agreed with observations of the Milky Way. In a paradigm changing result, it was shown that the mean hot CGM mass is comparable to or larger than the mass contained in other phases of the CGM for L* galaxies. [Subhabrata Majumdar, Priyanka Singh (RRI), Biman B. Nath (RRI) & Joseph Silk]

AGN feedback with the Square Kilometre Array and implications for cluster physics and cosmology

AGN feedback is regarded as perhaps the most important non-gravitational process in galaxy clusters, providing useful constraints on large-scale structure formation. In view of upcoming data, particularly from radio surveys with next-generation facilities like SKA, along with major breakthroughs in X-ray sensitivity, high spatial and spectral resolutions, a review AGN feedback in galaxy clusters was presented along with its implications for future study of cluster physics and cluster cosmology. The current major issues regarding modelling of AGN feedback and its impact on the surrounding medium and the possible breakthroughs we can expect from the future multi-frequency SKA instrument was discussed. [Subhabrata Majumdar, Asif Iqbal (Kashmir University), Biman B Nath (RRI), Prateek Sharma (IISC), Ruta Kale (NCRA), Mahadev Pandge (Dayanand Science College, Latur), Somak Raychaudhury (IUCAA) and Manzoor Malik (Kashmir University)]

Correlations of the feedback energy and BCG radio luminosity in galaxy clusters

The excess entropy and the corresponding non-gravitational feedback energy ($E_{\text{feedback}}$) in the intra-cluster medium (ICM) was studied by considering a sample of 22 galaxy clusters using Chandra X-ray and NRAO VLA Sky Survey (NVSS)/Giant Metre-wave Radio Telescope (GMRT) radio observations. Moderate to strong correlation of the brightest cluster galaxy (BCG) radio luminosity ($L_R$) with the feedback energy and various other cluster thermal properties were found. It was shown conclusively that the active galactic nucleus (AGN) is more efficient in transferring feedback energy to the ICM in less massive clusters. Finally, the implications of the results with regard to feedback in clusters and cosmology were discussed. [Subhabrata Majumdar, Asif Iqbal (RRI), Ruta Kale (NCRA) and Biman B. Nath (RRI)]
Constraining the X-ray AGN halo occupation distribution: implications for eROSITA

The X-ray emission from active galactic nucleus (AGN) is a major component of extra-galactic X-ray sky. The X-ray luminosity function (XLF) and halo occupation distribution (HOD) formalism was used to construct a halo model for the X-ray emission from AGNs. Verifying that the two inputs (XLF and HOD) are in agreement with each other, the auto-correlation power spectrum in the soft X-ray band (0.5-2 keV) was computed due to the AGNs potentially resolved by eROSITA (extended ROentgen Survey with an Imaging Telescope Array) mission and the redshift and mass dependence of the power spectrum were explored. Studying the relative contribution of the Poisson and the clustering terms to the total power, it was found that at multipoles $l < 1000$ (i.e. large scales), the clustering term is larger than the Poisson term. The potential of X-ray auto-correlation power spectrum and X-ray-lensing cross-correlation power spectrum using eROSITA and eROSITA-LSSST (Large Synoptic Survey Telescope) surveys, respectively, to constrain the HOD parameters and their redshift evolution were also forecasted. In addition, the power spectrum of the AGNs lying below the flux resolution limit of eROSITA was computed, which is essential to understand in order to extract the X-ray signal from the hot di use gas present in galaxies and clusters. [Subhabrata Majumdar, Priyanka Singh (RRI), Alexandre Refregier (ETH Zurich) and Biman B. Nath (RRI)]

Excess entropy and energy feedback from within cluster cores up to $r_{200}$

The non-gravitational entropy injection profiles, $K(m_g)$, and resulting non-gravitational energy feedback profiles, $E(m_g)$, of the intracluster medium for a sample of 17 clusters were estimated using the joint data sets of Planck SZ and ROSAT X-Ray observations, spanning a large radial range from $0.2r_{500}$ up to $r_{200}$. The non-thermal pressure and clumping were included in the analysis since they become important at larger radii. The inclusion of non-thermal pressure and clumping resulted in changing the estimates for $r_{500}$ and $r_{200}$ by 10%-20%. It was shown that neglect of clumping leads to an under-estimation of $K \sim 300$ keV cm$^2$ at $r_{500}$ and $K \sim 1100$ keV cm$^2$ at $r_{200}$. On the other hand, neglecting non-thermal pressure resulted in the over-estimation of $K \sim 100$ keV cm$^2$ at $r_{500}$ and under-estimation of $K \sim 450$ keV cm$^2$ at $r_{200}$. Combining both, it was conclusively shown that for the sample as a whole, an entropy floor of $K \sim 300$ keV cm$^2$ is ruled out at 3-sigma throughout the entire radial range and hence strongly constraining all ICM pre-heating scenarios. Moreover, it was found that the average feedback energy per particle of $E \sim 1$ keV is also ruled out at more than 3-sigma beyond $r_{500}$. The robustness of our results w.r.t sample selection, X-Ray analysis procedures, non-radiative entropy modeling were demonstrated. [Subhabrata Majumdar, Asif Iqbal (Kashmir University), Biman B Nath (RRI, Bangalore), Stefano Ettori (INFN Bologna), Dominique Eckert (University of Geneva) and Manzoor A. Malik (Kashmir University)]

Theia: Faint objects in motion or the new astrometry frontier

In the context of the ESA M5 (medium mission) call, a new satellite mission, Theia, based on relative astrometry and extreme precision to study the motion of very faint objects in the Universe was proposed. Theia is primarily designed to study the local dark matter properties, the existence of Earth-like exoplanets in our nearest star systems and the physics of compact objects. Furthermore, about 15% of the mission time is dedicated to an open observatory for the wider community to propose complementary science cases. With its unique metrology system and “point and stare” strategy, Theia’s precision would have reached the sub micro-arcsecond level. This is about 1000 times better than ESA/Gaia’s accuracy for the brightest objects and represents a factor 10-30 improvement for the faintest stars (depending on the exact observational program). In the version submitted to ESA, an optical (350-1000nm) on-axis TMA telescope was proposed. Due to ESA Technology readiness level, the camera’s focal plane would have been made of CCD detectors but it is anticipated that an upgrade with CMOS detectors will be possible. Photometric measurements would have been performed during slew time and stabilisation phases needed for reaching the required astrometric precision. [Subhabrata Majumdar and the THEIA Collaboration]

Fast flavor conversions of supernova neutrinos: Classifying instabilities via dispersion relations

Very recently, a novel method has been proposed to investigate fast flavor conversions of supernova neutrinos, in terms of the dispersion relation for the complex frequency and wave number of disturbances in the mean field of the flavor coherence. A systematic approach to such instabilities, originally developed in
the context of plasma physics, and based on the time-asymptotic behavior of the Green’s function of the system was discussed. Instabilities are typically seen to emerge for complex frequency, and can be further characterized as convective (moving away faster than they spread) and absolute (growing locally), depending on k-dependent features. Stable cases emerge when the wavenumber (but not frequency) is complex, leading to disturbances damped in space, or when both are real, corresponding to complete stability. The analytical classification of both unstable and stable modes leads not only to qualitative insights about their features but also to quantitative predictions about the growth rates of instabilities. Representative numerical solutions were discussed in a simple two-beam model of interacting neutrinos. As an application, it was argued that supernova and binary neutron star mergers exhibiting a “crossing” in the electron lepton number would lead to an absolute instability in the flavor content of the neutrino gas [Francesco Capozzi, Basudeb Dasgupta, Eligio Lisi, Antonio Marrone, and Alessandro Mirizzi]

Fast neutrino flavor conversion as oscillations in a quartic Potential

An analytical treatment of the simplest system that exhibits fast conversions was presented, and it was shown that the conversion can be understood as the dynamics of a particle rolling down in a quartic potential governed dominantly by the neutrino density, but seeded by slower oscillations. [Basudeb Dasgupta and Manibrata Sen]

New dissipation mechanisms from multi-level dark matter scattering

Multi-level dark matter with diagonal and off-diagonal interactions shows a rich phenomenology in its self-scattering. If the interactions are mediated by a particle that is less massive than the dark matter, Sommerfeld effect can lead to resonant enhancement of the scattering. For mediators lighter than the level separation, dark matter particles can up-scatter to excited states and de-excite by emitting these mediators. These cross-sections, both above and below the kinematic threshold were computed in a generic two-component dark matter model and the large inelastic cross-section as a result of maximal mixing between the two states was found. A new route for cooling of large dark matter halos and a new drag force between two colliding halos are identified and shown to arise purely from the inelastic scattering. [Anirban Das and Basudeb Dasgupta]

Selection Rule for Enhanced Dark Matter Annihilation

Multi-level dark matter with diagonal and off-diagonal interactions shows a rich phenomenology. A selection rule for enhancement (suppression) of odd (even) partial waves of dark matter co-annihilation or annihilation using Sommerfeld effect was pointed out. Using this, the usually velocity-suppressed p-wave annihilation was shown to dominate the annihilation signals in the present Universe. The selection mechanism is a manifestation of the exchange symmetry of identical incoming particles, and generic for multi-state DM with off-diagonal long-range interactions. As a consequence, the relic and late-time annihilation rates are parametrically different and a distinctive phenomenology, with large but strongly velocity-dependent annihilation rates, was predicted. [Anirban Das and Basudeb Dasgupta]

Fast neutrino flavor conversions near the supernova core with realistic flavor-dependent angular distributions

Using linear stability analyses and numerical solutions of the fully nonlinear equations of motion, a detailed study of fast conversions was performed, focusing on the region just above the supernova core and it was found that neutrinos travelling towards the core make fast conversions more generic, i.e., possible for a wider range of flux ratios and angular asymmetries. Using fluxes and angular distributions predicted by supernova simulations, it was found that fast conversions can occur within tens of nanoseconds, only a few meters away from the putative neutrinospheres. [Basudeb Dasgupta, Alessandro Mirizzi, and Manibrata Sen]

Polarized anisotropic spectral distortions of the CMB from photon-axion/scalar conversion

CMB photons can convert to axions or light scalar particles, as they propagate through the cosmos, in the presence of magnetic fields, resulting in a deviation of the CMB spectrum from a blackbody. The spectral distortions in the CMB photons from conversion (disappearance) to light spin-zero particles as they propagate through the galactic magnetic fields was calculated. It was shown that resonant conversion happens for axion masses between 10^{-14} and 5x10^{-13} eV giving rise to a polarized anisotropy pattern in the microwave sky (shown in figure). The anisotropy
pattern varies with particle mass and the polarization direction for scalar and pseudo-scalar particles is orthogonal to each other. Some inaccuracies in cosmological axion constraints in existing literature were pointed out. Un-polarized distortions from stochastic magnetic fields, in our Galaxy as well as in nearby voids, was also estimated. [Suvodip Mukherjee (IAP, Paris), Rishi Khatri, Benjamin Wandelt (IAP, Paris)]

**Dark neutrino interactions make primordial gravitational waves blue**

New interactions of neutrinos with dark matter were shown to significantly affect the evolution of the primordial gravitational waves and their imprints on the CMB B-mode polarization power spectrum. It was also shown that very generally there are two class of models having neutrino dark matter elastic scattering cross section either constant or with neutrino temperature dependence of $T^2$. Neutrino dark matter interactions were shown to enhance the CMB B-mode polarization power spectrum on small scales for modes with angular wavenumber $l>100$. Our results implied potential degeneracy with primordial (inflationary) gravitational wave power spectrum as well as a new window into neutrino physics from measurements of primordial B-mode polarization power spectrum of the CMB. [Subhajit Ghosh, Rishi Khatri, Tuhin Roy]

**New viable region of an inert Higgs doublet dark matter model with scotogenic extension**

We explored the intermediate dark matter mass regime of the inert Higgs doublet model, approximately between 400 GeV and 550 GeV, which is allowed by latest constraints from direct and indirect detection experiments, but the thermal relic abundance remains suppressed. We extended the model by three copies of right-handed neutrinos, odd under the built-in $Z_2$ symmetry of the model. This discrete $Z_2$ symmetry of the model allows these right-handed neutrinos to couple to the usual lepton doublets through the inert Higgs doublet allowing the possibility of radiative neutrino mass in the scotogenic fashion. Apart from generating nonzero neutrino mass, such an extension can also revive the intermediate dark matter mass regime. The late decay of the lightest right-handed neutrino to dark matter makes it possible for the usual thermally under-abundant dark matter in this intermediate mass regime to satisfy the correct relic abundance limit. The revival of this wide intermediate mass range can have relevance not only for direct and indirect search experiments but also for neutrino experiments as the long lifetime of the lightest right-handed neutrino also results in almost vanishing lightest neutrino mass. [Aritra Gupta, Debashis Borah (IIT Guwahati)]

**Condensed Matter and Statistical Physics**

**From Continuous transitions to Metamagnetism in 2 dimensional J$Q$ Model**

Using a combination of quantum Monte Carlo (QMC) and exact methods, the field-driven saturation transition of the two-dimensional $J$-$Q$ model was studied. For small values of $Q$, the saturation transition is continuous, and is expected to be governed by zero-scale-factor universality at its upper critical dimension, with a specific form of logarithmic corrections to scaling. Results conforming to this expectation were obtained, but the logarithmic corrections to scaling do not match the form predicted by Sachdev et al. It was shown that the saturation transition becomes first order above a critical coupling ratio $(Q/J)_{\text{min}}$ and is accompanied by magnetization jumps--metamagnetism. An exact solution for $(Q/J)_{\text{min}}$ using a high magnetization expansion was obtained, and confirmed the existence of the magnetization jumps beyond this value of coupling using quantum Monte Carlo simulations. [K. Damle, A. Sandvik and A. Iaizii (Boston University)]

**Realization of Multi-mode Superconducting Circuits as multiple qubits**
Inter-qubit coupling and qubit connectivity in a processor are crucial for achieving high fidelity multi-qubit gates and efficient implementation of quantum algorithms. Typical superconducting processors employ relatively weak transverse inter-qubit coupling which are activated via frequency tuning or microwave drives. This work proposed a class of multi-mode superconducting circuits which realize multiple transmon qubits with all-to-all longitudinal coupling. These "artificial molecules" directly implement a multidimensional Hilbert space that can be easily manipulated due to the always-on longitudinal coupling. The basic technique to analyze such circuits was described, and used to compute the relevant properties and discuss how to optimize them to create efficient small-scale quantum processors with universal programmability [Tanay Roy, Madhavi Chand, Sumem Hazra, Suman Kundu, Kedar Damle, R. Vijay]

Competing electronic phases in the topological crystalline insulator Pb(1-x)Sn(x)Te

The four topologically protected electron bands on the (001) surface of the crystalline topological insulator Pb(x)Sn(1-x)Te include two containing Type-II van Hove singularities, accessible at relatively small values of doping. Bloch states corresponding to electrons in these bands have nontrivial Berry phases that effectively impart a momentum dependence to the interparticle interactions in a given band. Using a “multipath” parquet renormalization group scheme, the authors studied the effect of repulsive electron interactions on the competition of different electronic phases on the (001) surface when the chemical potential is tuned to the vicinity of the van Hove singularities. Over a wide region of parameter space of repulsive interactions, it was shown that a chiral p-wave superconducting phase is favoured. In a subsequent paper, the authors studied the effect of a finite magnetization on the electronic phase competition. Implications for experiment were discussed. [V. Tripathi, S. Kundu]

Scaling universality at the dynamic vortex Mott transition

A clean way to observe a dynamic Mott insulator-to-metal transition (DMT) without the interference from disorder and other effects inherent to electronic and atomic systems, is to employ the vortex Mott states formed by superconducting vortices in a regular array of pinning sites. In this joint experiment-theory effort, the authors studied the critical behaviour of the vortex system as it crosses the DMT line, driven by either current or temperature. They found universal scaling with respect to both, expressed by the same scaling function and characterized by a single critical exponent coinciding with the exponent for the thermodynamic Mott transition. A theory for the DMT was developed based on the parity reflection-time reversal (PT) symmetry breaking formalism. It was found that the nonequilibrium-induced Mott transition has the same critical behavior as the thermal Mott transition. These findings demonstrate the existence of physical systems in which the effect of a nonequilibrium drive is to generate an effective temperature and hence the transition belonging in the same universality class as the temperature driven transition. [V. Tripathi, M. Lankhorst, M. P. Stenho, F. Coneri, H. Hilgenkamp, A. Brinkman and A. Golubov (Twente), N. Poccia (Harvard), A. Gald, T. Baturina and V. Vinokur (Argonne), and H. Barman (TIFR & IMSc)]

Power Law Tails in non-Markovian Dynamics of Open Quantum Systems

The dynamics of open Bosonic and Fermionic systems coupled linearly to thermal baths were investigated in this work using Keldysh Field Theory. It was shown that the dynamics of a system of bosons (fermions) linearly coupled to a noninteracting bosonic (fermionic) bath falls outside the standard Markovian paradigm if the bath spectral function has nonanalyticities as a function of frequency. In that case, the dissipative and noise kernels governing the dynamics were shown to have distinct power-law tails. The Green’s functions show a short-time “quasi”- Markovian exponential decay before crossing over to a power-law tail governed by the nonanalyticity of the spectral function. Exact solutions were found for a large class of non-analytic baths and it was shown that the power law tails are easier to observe at strong system bath coupling in unequal time correlators. It was shown that the power law tails were perturbatically robust to inter-particle interaction. [R. Sensarma, A. Chakraborty]

Braids and phase gates through high-frequency virtual tunneling of Majorana zero modes

Braiding of non-Abelian Majorana anyons is a first step towards using them in quantum computing. In this work a protocol was proposed for braiding Majorana zero modes formed at the edges of nanowires with strong spin-orbit coupling and proximity-induced superconductivity. The protocol uses high-frequency
virtual tunneling between the ends of the nanowires in a trijunction, which leads to an effective low-frequency coarse-grained dynamics for the system, to perform the braid. The braiding operation is immune to amplitude noise in the drives and depends only on relative phase between the drives, which can be controlled by the usual phase-locking techniques. It was also shown, how a phase gate, which is necessary for universal quantum computation, can be implemented with our protocol. [R. Sensarma, P. Gorantla]

Landau level diagram and the continuous rotational symmetry breaking in trilayer graphene

Sequence of the zeroth Landau levels (LLs) between filling factors -6 and 6 in ABA stacked trilayer graphene (TLG) is ambiguous because it depends sensitively on the non-uniform charge distribution on the three layers of ABA-TLG. Using the sensitivity of quantum Hall (QH) data on the perpendicular electric field $E$ and magnetic field $B$, in an ultraclean TLG sample, experimental data and theoretical modeling was used to quantitatively estimate the non-uniformity of the electric field and determine the sequence of the zeroth LLs. Anticrossings between some LLs differing by 3 in LL index were observed, and were explained as a result of the breaking of the continuous rotational to $C_3$ symmetry by trigonal warping. Some fractional quantum Hall (FQH) states at low magnetic field were also observed in this sample. [R. Sensarma, Biswajit Datta, Hitesh Agarwal, Abhishek Samanta, Amulya Ratnakar (CEBS, Mumbai University), Kenji Watanabe (NIMS Japan), Takashi Taniguchi (NIMS Japan) and Mandar M. Deshmukh]

Large deviations conditioned on empirical measure

In studies of stochastic processes, an important question deals with characterization of fluctuations conditioned on an empirical measure. Such conditioned processes have been studied in probability theory and computer science. Their relevance in Physics comes from thermodynamic ensembles and their generalization in non-equilibrium stationary state. In two long papers, we looked into stochastic processes when conditioned on an empirical observable, e.g. time integrated current. The first paper presented a formal analysis of conditioned Markov chain and Langevin dynamics. The second paper dealt with generalization of our framework to fluctuating hydrodynamics fields, in particular, application to systems of interacting many degrees of freedom. The results were verified by exact solution of few non-trivial microscopic models of interacting particles. [Tridib Sadhu, Bernard Derrida (Collège-de-France, Paris)]

**Generalized arcsine law for fractional Brownian motion**

The three arcsine laws for standard Brownian motion are well known pedagogical results in the theory of stochastic process. For a Brownian motion starting at the origin, and evolving during time $T$, one considers the following three observables: (i) the time $t_+$ the process is positive, (ii) the last time $t_{\text{last}}$ the process visits the origin, and (iii) the time $t_{\text{max}}$ it takes its maximum (or minimum). All three observables have the same cumulative probability distribution expressed as an arcsine function, hence the name arcsine law. We studied how these laws change for the fractional Brownian motion, which is a non-Markovian generalization of the Brownian motion. Using a tedious and challenging calculation we obtained generalization of all three arcsine laws. The theoretical results were supported (see figure) by extensive numerical simulations, which itself was challenging due to its non-Markovian nature. [Tridib Sadhu, Kay J Weise (Ecole Normale Supérieure, Paris)]

![Comparison of theoretical results of the three probabilities to their numerical simulation results.](image)

**Phase transition in one-dimensional system with short-range interactions**

There is a misconception, widely shared amongst physicists, that the equilibrium free energy of a one-dimensional model with strictly finite-ranged interactions, and at non-zero temperatures, cannot show any singularities as a function of the coupling constants. We presented an instructive counter-example. We considered thin rigid linear rods of equal length $2L$ whose centers lie on a 1-d lattice, of lattice
spacing a. The interaction between rods is a repulsive soft-core interaction, having energy $U$ per overlap of rods. We showed that the equilibrium free energy per rod $F(\kappa=L/a)$ has an infinite number of singularities, as a function of $\kappa$ (see figure). [Tridib Sadhu, Deepak Dhar and Sushant Sarlay (IISER, Pune), and Juliane U. Klamser (Ecole Normale Supérieure, Paris)]

Singularity in the derivative of free energy $F'(\kappa)$. (inset: shows the free energy)

Dynamical phase transition in a non-equilibrium steady state

Many recent works show phase transitions in the path-space measure in the non-equilibrium steady state of interacting particle systems. Drawing parallel with equilibrium phase transitions one may ask: are these phase transitions related to a non-analytic state function, similar to free energy? In one of the simplest setting of a single Brownian particle in a circular trap we analytically showed that the system undergoes a dynamical transition in the optimal paths, and the transition was related to non-analyticity of large deviations function of the particle position. The non-analyticity and the transition was then observed in an experimental realization of a diffusive bead confined in a circular potential generated in an optical tweezer setup. [Tridib Sadhu, Harsh Jain and Shankar Ghosh]

Multi-time correlation in driven diffusive system

Multi-time correlation of fluctuating quantities plays an important role in statistical mechanics. For example, within linear response theory, response function is expressed in terms of two-time correlation of the fluctuating observable. Using a variational formulation, we presented a systematic analysis of multi-time correlations of current in general diffusive systems out-of-equilibrium. A corollary of the work is an electrostatic correspondence providing an effective description of generic long-range correlation in non-equilibrium steady state, encompassing a large class of older works. In addition, the work presented a formal solution for the large deviation of density in non-equilibrium steady state of general diffusive systems. [Tridib Sadhu]

High Energy Physics

Non-standard self-interactions of supernova neutrinos

New possible effects of non-standard self-interactions (NSSI) of neutrinos on flavor conversions of supernova neutrinos were explored in a two-flavor framework. Flavor-preserving NSSI were shown to lead to pinching of spectral swaps, and an overall suppression of bipolar oscillations. Flavor-violating NSSI were shown to cause swaps to develop away from a spectral crossing or even in the absence of a spectral crossing. NSSI could then give rise to collective oscillations and spectral splits even during neutronization burst, for both hierarchies. [Anirban Das, Amol Dighe, and Manibrata Sen]

The standard linear stability analysis was shown to give rise to linearly as well as exponentially growing solutions in the presence of NSSI, and hence, to lead to “fast” oscillations at $r \sim 10$ km. In the intersecting four-beam model, it was pointed out that flavor-violating NSSI can lead to fast oscillations even when the angle between the neutrino and antineutrino beams is obtuse, which is forbidden in the Standard Model. This leads to the new possibility of fast oscillations in a two-beam system with opposing neutrino-antineutrino fluxes, even in the absence of any spatial inhomogeneities. The long-time behavior of fast and slow flavor conversions was explored by solving the full non-linear equations of motion in the four-beam model numerically. [Amol Dighe and Manibrata Sen]

Hadron direction reconstruction at INO-ICAL

The ability of the proposed iron calorimeter (ICAL) detector at the India-based Neutrino Observatory (INO) to determine hadron shower direction was determined through simulations. The directions of hadron showers in charged-current interactions were reconstructed using the orientation matrix method, while for neutral-current events, the raw-hit method
was used which did not need knowledge about the interaction vertex. [Moon Moon Devi, Amol Dighe, D. Indumathi, and S. M. Lakshmi]

**Ωc baryons**

We presented the ground and excited state spectra of Ωc baryons with spin up to 7/2 from lattice quantum chromodynamics with dynamical quark fields. Based on our lattice results, we predicted the quantum numbers of five Ωc baryons, which have recently been observed by the LHCb Collaboration. Our results strongly indicate that the observed states Ωc(3000) and Ωc(3050) have spin-parity J/P=1/2(−), the states Ωc(3066) and Ωc(3090) have J/P=3/2(−), whereas Ωc(3119) is possibly a 5/2(−) state. [Nilmani Mathur, M. Padmanath of University of Regensburg]

**Tetraquark states**

We presented preliminary results from a lattice calculation of tetraquark states in the charm and bottom sector of the type udcc, usbb, udcc usbb, udcc and usbb. These calculations were performed on Nf=2+1+1 MILC ensembles with lattice spacing of a=0.12fm and a=0.06fm. A relativistic action with overlap fermions was employed for the light and charm quarks while a non-relativistic action with non-perturbatively improved coefficients is used in the bottom sector. Our preliminary results provide a clear indication of presence of energy levels below the relevant thresholds of different tetraquark states. While in double charm sector we found shallow bound levels, our results suggest deeply bound levels with double bottom tetraquarks. [Nilmani Mathur, P. Junnarkar]

**Baryon spectra**

We presented preliminary results on the light, charmed and bottom baryon spectra using overlap valence quarks on the background of 2+1+1 flavours HISQ gauge configurations of the MILC collaboration. These calculations were performed on three different gauge ensembles at three lattice spacings (a ~ 0.12 fm, 0.09 fm and 0.06 fm) and for physical strange, charm and bottom quark masses. The SU(2) heavy baryon chiral perturbation theory is used to extrapolate baryon masses to the physical pion mass and the continuum limit extrapolations are also performed. Our results are consistent with the well measured charmed baryons. We predicted the masses of many other states which are yet to be discovered. [Nilmani Mathur, S. Mondal, and M. Padmanath (University of Regensburg)]

**Probing non-commutativity of space**

Non-commutative (NC) space-time geometry arises naturally in the context of string theory. An obvious question to ask is whether observational constraints can be placed on the scale of non-commutativity (measured in m^2). It has been argued earlier that Lamb shift measurements in Hydrogen can potentially reveal this scale while others have argued that no such effect is possible since proton and electron have equal and opposite charges. On the other hand, proton is made up of quarks with 2/3 and -1/3 charges, suggesting an effect may be possible at some scale. Examining quantum electrodynamics in NC-space, and for composite proton operator, it was shown that it) any charge g for a fermion is allowed provided the basic QED coupling is g, but no other multiples of g are permitted, thus only up (2/3 charge) or down (-1/3) is possible but not both and ii) composite operators do not have a simple transformation which can be attributed to effective total charge of the composite particle. This places limit on the scale of non-commutativity to be smaller that current LHC limits for compositeness. It also suggests that a substructure at still smaller scales is needed if NC-geometry is to be a physical reality. [R. V. Gavai, P. S. Ghoderao (IIT Mumbai), P. Ramadevi (IIT Mumbai)]

**Study of Quarkonia in QGP using effective field theory**

Quarkonia are some of the most important probes of the medium created in relativistic heavy ion collision experiments, but it is still difficult to get quantitative predictions of its behavior in quark-gluon plasma from QCD. A combination of effective field theory techniques with nonperturbative determination of their coefficients from QCD may allow us to make reliable theoretical calculations for such systems. As part of this ongoing project, I have estimated decay width of heavy quarkonia in the plasma. [Saumen Datta]

**Quark number susceptibilities and equation of state at finite mu**

Direct numerical studies of nonperturbative QCD at finite baryon chemical potential mu are not possible. A method employing Taylor expansion in mu, suggested from TIFR, has turned out to be the most successful method for calculations at finite mu. The coefficients of such expansion, quark number susceptibilities (QNS), are important experimental observables in their
own right. As continuation of the finite mu program in TIFR, We are studying QCD on fine (Nt=12) lattices with two flavors of dynamical quarks with the aim of calculating the QNS. Combining with earlier results on coarser lattices allows us to calculate the continuum equation of state at finite mu and make an estimate of the location of the critical point in QCD phase diagram. [Saumen Datta, R. Gavai and S. Gupta]

**A Universal Framework for Finding Anomalous Objects at the LHC**

There are examples aplenty where new physics (NP) gives rise to anomalous objects, which cannot be classified as any of the standard-objects (such as isolated-photons, leptons, and QCD-jets). The need for a generic method/tool capable of finding the unexpected cannot be understated. In this paper, we propose one such anomaly-finder, which simply is a collection of vetoes that eliminates all standard-objects up to a pre-determined acceptance rate. Events containing anomalous objects can be identified as a candidate for NP. Subsequent offline analyses can determine the exact nature of the event, paving a robust way to search for NP scenarios in a model-independent fashion. Further, since the method relies on learning only the standard-objects, for which control samples are readily available from data, one can build an analysis in entirely data-driven ways. [Tuhin Roy, Amit Chakraborty and Abhishek Iyer]

**Charting Generalized Supersoft Supersymmetry**

In the context of supersoft supersymmetry, I recently proposed new solutions to the μ-problem, color breaking problem, and too-large a T parameter, via a new class of operators (namely, NR-operators), built using the D-vev of a real spurion. In this work we point out that the last remaining issue associated with supersoft spectra (namely that a right-handed (RH) slepton is predicted to be the lightest superpartner, rendering the setup cosmologically unfeasible) can be addressed. NR-operators generate a new source for scalar masses, which can raise the RH-slepton mass above bino due to corrections from renormalisation group evolutions (RGEs). In fact, a mild tuning can open up the bino-RH slepton co-annihilation regime for a thermal dark matter. By deriving the full set of RGEs, we show that a completely viable spectra can be achieved. [Tuhin Roy, Adam Martin (University of Notre Dame) and Sabysachi Chakraborty].

**Collisional and thermal dissociation of J/Psi and Upsilon states at the LHC**

We presented new results for the suppression of high transverse momentum charmonium \([J/\Psi,Psi(2S)]\) and bottomonium \([Upsilon(1S),Upsilon(2S),Upsilon(3S)]\) states in Pb+Pb collisions at the Large Hadron Collider. Our theoretical formalism combines the collisional dissociation of quarkonia, as they propagate in the quark-gluon plasma, with the thermal wavefunction effects due to the screening of the \(Q\bar{Q}\) attractive potential in the medium. We found that a good description of the relative suppression of the ground and higher excited quarkonium states, transverse momentum and centrality distributions is achieved, when comparison to measurements at a center-of-mass energy of 2.76 TeV is performed. Theoretical predictions for the highest Pb+Pb center-of-mass energy of 5.02 TeV at the LHC, where new experimental results are being finalized, are also presented. [Samuel Aronson (UCSB), Evan Borras (UCSB), Brunel Odegard (UCSB), Rishi Sharma, Ivan Vitev (LANL)]

**Effective Field Theory Models for warm QCD**

Using only global symmetries of QCD, we set up an effective model of two flavors of quarks at finite temperature near the crossover, including all possible terms up to dimension-6. We first treat this in mean field theory. Then we investigate low-energy fluctuations around it up to one-loop order in fermions below the crossover. Static correlation functions of pions and the crossover temperature, both measured on the lattice, completely suffice to fix all parameters of the theory. We examine predictions of this theory, including those for thermodynamic quantities. The results are encouraging. In particular, the pion decay constant as a function of the temperature is an independent prediction and matches well with the lattice observations. [Sourendu Gupta, Rishi Sharma]

**Current constraints on mixed Higgs-radion states and the possibility of discovering them in the future runs of the LHC**

Light radions constitute one of the few surviving possibilities for observable new particle states at the sub-TeV level which arise in models with extra spacetime dimensions. It is already known that the 125 GeV scalar discovered at CERN is unlikely to be a pure radion state, since its decays resemble those of the
Standard Model Higgs boson too closely. However, due to experimental errors in the measured decay widths, the possibility still remains that it could be a mixture of the radion with one (or more) Higgs states. We used the existing LHC data at 8 and 13 TeV to make a thorough investigation of this possibility. Not surprisingly, it turned out that this model is already constrained quite effectively by direct LHC searches for an additional scalar heavier than 125 GeV. We then made a detailed study of the so-called 'conformal point', where this heavy state practically decouples from (most of) the Standard Model fields. Some projections were made for the future runs of the LHC.

**String Theory and Mathematical Physics**

### The Dynamics of Near-Extremal Black Holes

We analyse the dynamics of near-extremal Reissner-Nordström black holes in asymptotically four-dimensional Anti-de Sitter space (AdS4). We work in the spherically symmetric approximation and study the thermodynamics and the response to a probe scalar field. We find that the behaviour of the system, at low energies and to leading order in our approximations, is well described by the Jackiw-Teitelboim (JT) model of gravity. In fact, this behaviour can be understood from symmetry considerations and arises due to the breaking of time reparametrisation invariance. The JT model has been analysed in considerable detail recently and related to the behaviour of the SYK model. Our results indicate that features in these models which arise from symmetry considerations alone are more general and present quite universally in near-extremal black holes. [Pranjal Nayak, Ashish Shukla, Ronak M Soni, Sandip P. Trivedi, V. Vishal]

### An Action for and Hydrodynamics from the improved Large D membrane

It has recently been demonstrated that black hole dynamics at large \( D \) is dual to the motion of a probe membrane propagating in the background of a spacetime that solves Einstein's equations. The equation of motion of this membrane is determined by the membrane stress tensor. In this paper we `improve' the membrane stress tensor derived in earlier work to ensure that it defines consistent probe membrane dynamics even at finite \( D \) while reducing to previous results at large \( D \). Our improved stress tensor is the sum of a Brown York term and a fluid energy momentum tensor. The fluid has an unusual equation of state; its pressure is nontrivial but its energy density vanishes. We demonstrate that all stationary solutions of our membrane equations are produced by the extremization of an action functional of the membrane shape. Our action is an offshell generalization of the membrane's thermodynamic partition function. We demonstrate that the thermodynamics of static spherical membranes in flat space and global AdS space exactly reproduces the thermodynamics of the dual Schwarzschild black holes even at finite \( D \). We study the long wavelength dynamics of membranes in AdS space, and demonstrate that the boundary 'shadow' of this membrane dynamics is boundary hydrodynamics with a definite constitutive relation. We determine the explicit form of shadow dual boundary stress tensor up to second order in derivatives of the boundary temperature and velocity, and verify that this stress tensor agrees exactly with the fluid gravity stress tensor to first order in derivatives, but deviates from the later at second order and finite \( D \). [Yogesh Dandekar, Suman Kundu, Subhajit Mazumdar, Shiraz Minwalla, Amiya Mishra, Arunabha Saha.]

### Melonic O\((N)^{q-1}\) models

It has recently been demonstrated that the large \( N \) limit of a model of fermions charged under the global/gauge symmetry group \( O(N)\)^\((q-1)\) agrees with the large \( N \) limit of the SYK model. In these notes we investigate aspects of the dynamics of the \( O(N)^{q-1} \) theories that differ from their SYK counterparts. We argue that the spectrum of fluctuations about the finite temperature saddle point in these theories has \((q-1)\)^\((N^2/2)\) new light modes in addition to the light Schwarzian mode that exists even in the SYK model, suggesting that the bulk dual description of theories differ significantly if they both exist. We also study the thermal partition function of a mass deformed version of the SYK model. At large mass we show that the effective entropy of this theory grows with energy like \( E\ln E \) (i.e. faster than Hagedorn) up to energies of order \( N^2 \). The canonical partition function of the model displays a deconfinement or Hawking Page type phase transition at temperatures of order \( 1/\ln N \). We derive these results in the large mass limit but argue that they are qualitatively robust to small corrections in \( 1/m \).

[Sayantan Choudhury, Anshuman Dey, Indranil Halder, Lavneet Janagal, Shiraz Minwalla, Rohan Poojary]
Currents and Radiation from the large D Black Hole Membrane

It has recently been demonstrated that black hole dynamics in a large number of dimensions D reduces to the dynamics of a codimension one membrane propagating in flat space. In this paper we define a stress tensor and charge current on this membrane and explicitly determine these currents at low orders in the expansion in 1/D. We demonstrate that dynamical membrane equations of motion derived in earlier work are simply conservation equations for our stress tensor and charge current. Through the paper we focus on solutions of the membrane equations which vary on a time scale of order unity. Even though the charge current and stress tensor are not parametrically small in such solutions, we show that the radiation sourced by the corresponding membrane currents is generically of order (1/D)^D. In this regime it follows that the near horizon membrane degrees of freedom are decoupled from asymptotic flat space at every perturbative order in the 1/D expansion. We also define an entropy current on the membrane and use the Hawking area theorem to demonstrate that the divergence of the entropy current is pointwise non negative. We view this result as a local form of the second law of thermodynamics for membrane motion. [Sayantani Bhattacharyya (IIT Kanpur), Anup Kumar Mandal (IIT Kanpur), Mangesh Mandlik, Umang Mehta (IIT Bombay), Shiraz Minwalla, Utkarsh Sharma (IIT Bombay), Somyadip Thakur]

Two-dimensional quantum gravity dual to SYK/tensor models

The Nambu-Goldstone (NG) bosons of the SYK model are described by a coset space Diff/SL(2,R), where Diff, or Virasoro group, is the group of diffeomorphisms of the time coordinate valued on the real line or a circle. It is known that the coadjoint orbit action of Diff naturally turns out to be the two-dimensional quantum gravity action of Polyakov without cosmological constant, in a certain gauge, in an asymptotically flat spacetime. Motivated by this observation, we explore Polyakov action with cosmological constant and boundary terms, and study the possibility of such a two-dimensional quantum gravity model being the AdS dual to the low energy (NG) sector of the SYK model. We find strong evidences for this duality: (a) the bulk action admits an exact family of asymptotically AdS2 spacetimes, parameterized by Diff/SL(2,R), in addition to a fixed conformal factor of a simple functional form; (b) the bulk path integral reduces to a path integral over Diff/SL(2,R) with a Schwarzian action; (c) the low temperature free energy qualitatively agrees with that of the SYK model. We show, up to quadratic order, how to couple an infinite series of bulk scalars to the Polyakov model and show that it reproduces the coupling of the higher modes of the SYK model with the NG bosons. [Gautam Mandal, Pranjal Nayak, Spenta R. Wadia]

Solving conformal crossing equation

The conformal crossing equation puts very stringent constraints on the conformal data. We formulate it in a way that makes the conformal symmetry more transparent. This allows for generalization of the crossing equation to arbitrary Lie group G. Using the crossing equation for SU(2) as a toy model, we find infinitely many solutions to the G-crossing equation. In particular, when G is specialized to the conformal group SO(d+1,1), we get infinitely many solutions to the conformal crossing equation. [Abhijit Gadde]

Vector space of conformal field theories

It is argued that the space of not necessarily unitary conformal field theories with abelian symmetry forms a vector space over complex numbers. This is done by formulating the CFT consistency condition as factorization of the n-point function of a certain chosen operator. As a corollary we can construct a non-unitary conformal theory in any dimension. [Abhijit Gadde, Indranil Halder]

S-Matrix Bootstrap for Amplitudes with Linear Spectrum

We worked out constraints imposed by channel duality and analyticity on tree-level amplitudes of four identical real scalars, with the assumptions of a linear spectrum of exchanged particles and Regge asymptotic behaviour. We reduced the requirement of channel duality to a countably infinite set of equations in the general case. We showed that channel duality uniquely fixes the soft Regge behaviour of the amplitudes to that found in String theory, (s)^(-(2t)). Specialising to the case of tachyonic external particles, we used channel duality to show that the amplitude can be any one in an infinite-dimensional parameter space, and presented evidence that unitarity doesn't significantly reduce the dimension of the space of amplitudes. [Pranjal Nayak, Rohan Poojary, Ronak Soni]
**Asymptotic Symmetries of 3d Extended Supergravities**

We studied asymptotic symmetry algebras for classes of three dimensional supergravities with and without cosmological constant. In the first part we generalised some of the non-Dirichlet boundary conditions of AdS_3 gravity to extended supergravity theories, and computed their asymptotic symmetries. In particular, we showed that the boundary conditions proposed to holographically describe the chiral induced gravity and Liouville gravity do admit extension to the supergravity contexts with appropriate superalgebras as their asymptotic symmetry algebras. In the second part we considered generalisation of the 3d BMS computation to extended supergravities without cosmological constant, and showed that their asymptotic symmetry algebras provide examples of nonlinear extended superalgebras containing the BMS_3 algebra. [Rohan Poojary, Nemani Suryanarayana (IMSc)]

**Entanglement in Chern-Simons theory with generic gauge groups**

We study the entanglement for a state on linked torus boundaries in 3d Chern-Simons theory with a generic gauge group and present the asymptotic bounds of Rényi entropy at two different limits: (i) large Chern-Simons coupling k, and (ii) large rank r of the gauge group. These results show that the Rényi entropies cannot diverge faster than lnk and lnr, respectively. We focus on torus links T(2,2n) with topological linking number n. The Rényi entropy for these links shows a periodic structure in n and vanishes whenever n=0 (mod p), where the integer p is a function of coupling k and rank r. We highlight that the refined Chern-Simons link invariants can remove such a periodic structure in n. [Siddharth Dwivedi (IIT Bombay), Vivek Kumar Singh (IIT Bombay), Saswati Dhara (IIT Bombay), P. Ramadevi (IIT Bombay), Yang Zhou (Fudan University), Lata Kh Joshi]

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Gunnar Bali (Univ. of Regensburg, Germany), Gautam Bhattacharyya (SINP, Kolkata) [till December 31, 2017], Sumit R. Das (Univ. of Kentucky, USA), Satya N. Majumdar (CNRS, Univ. of Paris, France), Jean-Yves-Ollitrault (CNRS, France) [till April 30, 2017], Alexandre Refregier (ETH, Zurich) [till December 31, 2017]

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4. Member, Physics Sectional Committee, Indian Academy of Science
5. Member, SINP Academic Review Committee
6. Member, Academic Review Committee of Physics Department, IISER, Bhopal

Sourendu Gupta
1. Member, Editorial board of Pramana
2. Member, Sectional Committee for Physics, INSA

Subhabrata Majumdar
1. Team Leader, SZ and CMB-LSS Synergies, CMB Bharat proposal to ISRO
2. Core Member, ESA proposal ‘THEIA - The Universe in Motion
3. Core member, Red-Sequence Cluster Surveys -2 (RCS2)

Nilmani Mathur
Member, International Advisory Committee for the International Symposium on Lattice Field Theory

Shiraz Minwalla
1. Member, International Advisory Committee for Strings 2017
2. Member, Board of Management, ICTS, Bangalore

Sneerup Raychaudhuri
1. Member, Programme Advisory Committee of the ICTS-TIFR, 2014 –
2. Convenor, ‘Candles of Darkness 2017’, ICTS-TIFR
3. Joint Convenor, ‘SUSY-17’, TIFR, Mumbai, Dec 2017
4. Member, IOC, Asia-Europe-Pacific Schools on High Energy Physics, 2012 –

Tuhin S. Roy
Convener, Working group “Jetology” within the Indo-French Network in High Energy Physics (LIA THEP and CEFIPRA INFRE-HEPNET)

Tridib Sadhu
Associate member, ICTS-TIFR, Bengaluru, 2017-2020

Rajdeep Sensarma
Referee, Physical Review Letters, Physical Review B

Rishi Sharma
Editor, The European Physical Journal A

Vikram Tripathi
Editorial Board Member, Scientific Reports (Nature)

Sandip Trivedi
1. Fellow, The World Academy of Sciences, Trieste, Italy
2. Fellow, Indian Academy of Sciences, Bangalore
3. Fellow, Indian National Science Academy, New Delhi
Visits

Sabyasachi Chakraborty
Korea Institute for Advanced Studies, 27 Mar-6 April, 2017

Kedar Danle
ISSP University of Tokyo, April-July 2017

Basudeb Dasgupta
1. University of Pennsylvania, USA, June - July 2017
2. University of Maryland, USA, 26 - 28 June 2017
3. Johns Hopkins University, USA, 25 June 2017
4. MTP, University of Mainz, Germany, 9 -13 Oct 2017

Rajir Garai
1. Saha Institute of Nuclear Physics, 10-12 August 2017
2. IISER, Bhopal, 12-16 December, 2017
3. IISER, Bhopal, 19-20 March, 2018

Aritra Gupta
Harish-Chandra Research Institute, Allahabad, Feb 2018

Sourendu Gupta
University of Bielefeld, Germany, October-November, 2017

Rishi Khatri
Max Planck Institute for Astrophysics, Garching, Germany, 24 May - 30 June 2017

Subhabrata Majumdar
1. MIAPP, LMU, Munich, March-April 2017
2. Paris Centre for Cosmological Physics, April 2-5, 2017
3. ICTS, Bangalore, June 5-9, 2017
4. ICTP, Trieste, June 27 - August 4, 2017
5. Durham University, July 24-26, 2017
6. Kavli Institute of Cosmology, Univ. of Cambridge, UK, July 26-29, 2017
7. IUCAA, Pune, October 9-12, 2017
8. ISRO, Bangalore, January 7-9, 2018
9. Osmania University, Hyderabad, February 6-8, 2018

Gautam Mandal
1. IMSc, Chennai, May 2017
2. Shizuoka University, Japan, 2-7 November 2017
3. YITP, Kyoto University, Japan, 8-13 November 2017

Shiraz Minwalla
ICTP, Trieste, May 1 to 31, 2017
IISER Pune, October 2017

Sneerup Raychaudhuri
1. University of Calcutta, Department of Physics, Kolkata, June 2017
2. NISER, Department of Physics, Bhubaneswar, November 2017
3. Laboratoire d’Annecy-le-Vieux de Physique Theorique, Annecy, France, Mar 2018
4. University of Oxford, Department of Physics, Oxford, UK, Mar 2018
5. University of Cambridge, DAMTP, Cambridge, UK, Mar 2018

Tuhin S. Ray
1. IISER Pune, February 26-28, 2018
2. IISER Bhopal, December 16-19, 2017
3. International Centre for Theoretical Sciences (ICTS), Bangalore, June 4-7, 2017

Trividh Saha
2. ICTS-TIFR, Bangalore, 28 June-14th July, 2017
4. ICTS-TIFR, Bangalore, 21 August to 5 September, 2017
5. IISER-Pune, 4 to 8 December 2017
6. Weizmann Institute of Science, 30 Dec- 13 Jan 2018
7. TCIS, TIFR-Hyderabad, 29 January to 2 February, 2018

Rajdeep Sensarma
1. IIT Kanpur, March 2017
2. IISc Bangalore, March 2017
3. JNU, New Delhi, March 2017
4. ICTS-TIFR, Bangalore, July 2017
5. IIT Guwahati, March 2018

Vikram Tripathi
Argonne National Laboratory, USA, 26 April - 02 June 2017

Invited Talks

Sabyasachi Chakraborty
1. Use of soft tracks in compressed SUSY, at
   a) SUSY17, TIFR, December 12, 2017
   b) WHEPP2017, IISER Bhopal, December 18, 2017
2. Viable framework for D-type SUSY breaking, at
   a) SUSY17, TIFR, December 14, 2017
   b) WHEPP2017, IISER Bhopal, December 19, 2017
3. Flavor anomalies and neutrino mass mixing in horizontal symmetric models. WHEP2017, IISER Bhopal, Dec 20, 2017

Kedar Danle
1. Multicritical melting of three-sublattice order. International School and Workshop on Frustrated Magnetism, IMSc Chennai, April 2017
2. Vacancy induced low energy states in graphene. OIST Seminar, Okinawa Japan, May 2018
3. Melting of three sublattice order. ISSP Seminar, Univ. of Tokyo, Japan, May 2018

Basudeb Dasgupta
1. Supernova Neutrinos: Theory and Future Detection. WIN 2017, University of California, Irvine, 19 June 2017
3. Selection Rules for Enhanced Dark Matter Annihilation
   a) Johns Hopkins University, Baltimore, 26 July 2017
   b) Particle Theory Seminar, University of Maryland, College Park, 27 July 2017

Saumen Datta
1. Nonperturbative study of heavy quarkonia in quark gluon plasma in: Nonperturbative and Numerical Approaches to Quantum Gravity. String Theory and Holography. ICTS-TIFR, Bengaluru, January 2018
2. Finite temperature QCD from lattice. Second Workshop of the Indo-French Network in High-Energy Physics, IISER, Pune, February 2018

Amit Gupta
1. Flavor data and new physics: hints and constraints. Belle Analysis Workshop, MNIT Jaipur, November 2017
3. India-based Neutrino Observatory (INO): science, technology, and opportunities. Indian Science Congress, Tirupati, January 2017
4. An overview of neutrino physics, Candles of Darkness. ICTS-TIFR, Bengaluru, June 2017

Abhijit Gadde
1. In search of conformal field theories. National String Meeting, Bhubaneshwar, December 2017
2. Conformal constraints on defects. IISER Pune, Feb 2018

Rajiv Gavai
4. An Exciting Odyssey in the Femto-World: QCD Critical Point. National Institute of Science Education & Research (NISER), Bhubaneshwar, 30 December 2017

Aritra Gupta
1. Boosted dark matter in IceCube. SUSY17, TIFR, December, 2017
2. Dark Matter and IceCube. WHEPP2017, IISER Bhopal December, 2017
3. Boosted dark matter in IceCube. BSM blues, 2018, TIFR January, 2018
4. New viable region of an inert Higgs doublet dark matter model with scotogenic extension. NuHorizons 2018, HRI, Allahabad February, 2018

Saurav Gupta
1. An effective theory for thermal QCD. ICTS-TIFR, Bangalore, 2 May, 2017
2. Effective thermal models from the lattice. CPOD 2017, Univ. of Stonybrook, USA, 9 August 2017
3. Hot Stuff, SPS, JNU, New Delhi, 24 August 2017
4. An effective theory for warm QCD. University of Bielefeld (Germany), 26 October 2017
5. An effective theory for warm QCD. IIT Indore, 10 January 2018
6. The Big Bang and effective theories. IIT Indore, 9 January 2018
7. An effective theory for warm QCD. Workshop on Nonperturbative and Numerical Aspects of Quantum Gravity and String Theory, ICTS, 1 February, 2018
8. The QCD medium. Indo-French Meeting, IISER Pune, 25-28 Feb, 2018

Rishi Khatri
1. The information hidden in the CMB spectral distortions
   a) 29th meeting of Indian Association for General Relativity & Gravitation, Guwhati, May 18-20 2017
   b) Gordon Research Conference, String Theory & Cosmology Renaissance Tuscany II Ciocco, Lucca (Barga) Italy, 28 May - 6 June 2017
   c) Conference on Post Planck Cosmology: Enigma, Challenges and Visions. Inter-University Centre for Astronomy and Astrophysics, Pune, Oct 9-12 2017
d) IUCAA, Pune, Jan 4, 2018
2. Spectral distortions of the CMB from photon-axion conversion. High energy astrophysics seminar, Max Planck Institute for Astrophysics, Garching, June 23, 2017
3. CMB spectral distortions with the next CMB mission. CMB Meeting, ISRO HQ Bangalore, Jan 8-9, 2018
4. Particle Physics from CMB. Workshop on Blueprints Beyond the Standard Model, January 5-18 2018

Subhabrata Majumdar
2. Non-gravitational entropy and energy ‘profiles’ in clusters - Implications for AGN feedback and Preheating, Kavli Institute for Cosmology, Cambridge, UK, July 28, 2017
4. Clusters, AGNs and Galaxies with eROSITA, Post Planck Cosmology. IUCAA, Pune, October 12, 2017
5. Fundamental Physics with CMBB-LSS interplay, Prospects for Indian Frontier CMB Mission. ISRO, Bangalore, Jan 2018
6. Missing baryons hidden in the Circumgalactic Medium. ASI meeting, Hyderabad, February 7, 2018

Gautam Mandal
1. Review of the SYK model, Modern Aspects of String Theory. IV Saha Theory Workshop, Saha Institute of Nuclear Physics, Kolkata, March 3-4, 2018
2. SYK model, Coadjoint orbits and Liouville bulk dual. Workshop on Holography and Quantum Dynamics, YITP, Kyoto University, 11 November 2017
3. Thermalization, holography and related topics. Entanglement Working Group meeting, YITP, Kyoto University, 9 November 2017
4. On aspects of SYK model. Shizuoka University, Japan, November 6, 2017
5. Treatment of shocks with $c = 1$ techniques. Bangalore area Strings meeting, ICTS, TIFR, Bangalore, 31 July 2017
6. SYK model, Coadjoint orbits and Liouville bulk dual. IMSc, Chennai, 11 May 2017

Nilmani Mathur
An Introduction to Lattice Quantum Chromodynamics. ICTS programme on Nonperturbative and Numerical Approaches to Quantum Gravity String Theory and Holography, ICTS-TIFR Bengaluru, 27 Jan - 03 Feb 2018

Shiraz Minwalla
1. Flows, Fixed Points and Duality in Matter Chern Simons Theory, at
   a) University of Torino, Turin, May 2017 
   b) ICTP, Trieste, May 2017
   c) Strings 2017, Tel Aviv, Israel, June 2017
2. Notes on Melonic Tensor models. Bangalore Area String Meeting, August 2017
3. An Action for and Hydrodynamics from the improved large D membrane. Twenty Years of AdS/CFT, Princeton, September 2017
4. The Large D membrane Paradigm. IISER, Pune, October 2017
5. Black Hole dynamics at large D'. NCRA, Pune, Colloquium, October 2017

Sreerup Raychaudhuri
1. The Early Days of Particle Physics in India, at
   a) PRL, Ahmedabad, July 2017
   b) HRI, Allahabad, October 2017
   c) IOP, Bhubaneswar – D.P. Roy Memorial Colloquium, November 2017
2. The Standard Model: Too Much of a Good Thing. BHU, October 2017
3. Flavour-changing Decays of the Top Quark in the LHC Context. Oxford University, Mar 2018

Tabin S. Ray
1. Lectures on jets & substructure - Part 2, Second Workshop of the Indo-French Network in High Energy Physics (LIA THEP and CEFIPRA INFRE-HEPNET), Indian Institute of Science Education and Research, Pune (IISER-Pune), February 2018

Tridib Sadhu
2. Extension of the arcsine law in fractional Brownian motion. LPTMS, Univ Orsay Paris-Sud, 9 May 2017
3. Conditioned stochastic processes, at
   a) Nonequilibrium Statistical Physics of Complex Systems, KIAS July 2018
   b) Entropic fluctuation relations in mathematics and physics, Universite de Montreal, October 2018
5. Long-range correlation in non-equilibrium stationary state. Workshop on large deviation in statistical Physics, ICTS-TIFR Bengaluru, 4September 2017
6. Functional of fractional Brownian motion. ISER Pune, 6 December 2017
7. Functional of fractional Brownian motion, Correlations, Fluctuations and anomalous transport in systems far from equilibrium. Weizmann Institute of Science, Israel, 3 January 2018

Rajdeep Sensarma
3. Interplay of Interactions and Band Structure in Few Layer Graphene. JNU March Meeting, JNU, March 2017
5. Interplay of Band Structure and Interactions in Few Layer Graphene. IACS APCPT Conference on Novel Quantum Phases in Oxide Materials and Low Dimensional Systems, Kolkata, November, 2017
6. Superconductivity from Doulbion Condensation. S.N. Bose Memorial Conference, SN Bose National Center
7. Superconductivity from Doublon Condensation. Recent Trends in Ultracold Matter, IIT Guwahati, March, 2018

Rishi Sharma
1. Effective theories of dense quark matter and applications in neutron stars, Candles of darkness, ICTS-TIFR, Bangalore, June, 2017
2. Towards an effective theory for the QCD crossover. 2nd workshop of the Indo French Network on High Energy Physics, IISc, Bengaluru, November 2017
3. An effective theory for warm QCD. NISER, Bhubaneshwar, India, November 2017
4. EFTs for finite temperature and finite density matter. WHEPP XV, IISER, Bhopal, December 2017
5. Suppression of high-pT quarkonia. QGP, 2018 Santa Fe Jets and Heavy Flavor Workshop, Santa Fe, USA, January 2018
6. Anistotropic shear viscosity. PRL Conference on Condensed Matter, PRL, Ahmedabad, March 2018

Vikram Tripathi
1. Competing electronic phases in the topological crystalline insulator Pb(x)Sn(1-x)Te. Moscow International Symposium on Magnetism, Moscow State University, Moscow, Russia, 4 July, 2017
2. Chiral p-wave superconducting order in the topological crystalline insulator Pb(x)Sn(1-x)Te. Recent trends in Quantum Matter, IIT Bombay, 6 December, 2017
4. Electronic instabilities in the topological crystalline insulator Pb(x)Sn(1-x)Te. IISc Bangalore, 9 February, 2018
5. Finite temperature insulator transition in a strongly disordered superconductor. Emergent Phenomena in Classical and Quantum Systems, S. N. Bose Institute, Kolkata, 26 February, 2018

Conference Organized by the Department

Student Talks on Trending Topics in Theoretical Physics (ST4) 2017
Chennai Mathematical Institute, Chennai, 8 – 19 May 2017 (Organisers: Pranjal Nayak, Rohan R. Poojary and Ronak M Soni, Vinay Mahimat (IIT Kanpur), Debangshu Mukherjee (CMI) and Madhusudhan Raman (IMSc))

Pune Mumbai Collider Meet 2017
IIT, Mumbai, 15 October 2017

25th International Conference on Supersymmetry & the Unification of Fundamental Interactions (SUSY17)
TIFR, Mumbai, December 11 - 15, 2017 (Co-convenor: Sreerup Raychaudhuri)

Blueprints Beyond the Standard Model Workshop
TIFR, Mumbai, 5-8 January, 2018

Department of Theoretical Physics Interaction Meeting
TIFR, February 8 and 9, 2018

Non-DAE Research Projects

Basudeb Dasgupta
1. Max-Planck Partner Group on Astroparticle Physics, June 2016 to June 2019 (Funded by Max Planck Society)
2. Ramanujan Fellowship Project, 2015–2020

Rajeev Bhaderao, Rajo Gavai, Sourendu Gupta, Sreerup Raychaudhuri, Tuhin Roy, K.Sridhar (with members from Indian and French institutes)
International Associated Laboratory (IJA) – Indo-French Collaboration in Theoretical High Energy Physics (IFTHEP), January 2015 to December 2018 (Funded by CNRS, France and DST, India); Coordinators: Rohini Godbole and Fawzi Boudjema.

Rishi Khatri
1. Digging new information from the Planck cosmic microwave background mission public data, SERB-DST, Sep 2016-2019
2. The information hidden in the cosmic microwave background spectrum, Max Planck Gesellschaft, Germany and DST India, July 2016–2019
Shiraz Minwalla (with Ofer Aharony, Weizmann Institute, Israel)
Field Theories with high-spin symmetries and high-spin gravities (Funded by India Israel Joint Research Project, 2014–2017)

Tuhin S. Ray
Scientific ballooning program is a key element for any space science program as it provides frequent, low-cost flight opportunities. It allows the scientists to build and fly payloads to conduct research on the Earth's environment including lower and upper atmosphere, ionosphere and magnetosphere, space plasma physics, astrobiology and high-energy astrophysics. Increasing operational requirements of these balloon-borne experiments necessitate relentless research & development (R&D) efforts in improving the design and development of plastic balloon, control instrumentation and launch facilities to meet the mission goals with distinction.

Balloon Designing and Fabrication

The following balloons with detailed specifications as given below were custom designed and fabricated at TIFR Balloon Facility, Hyderabad during April 2017 to March 2018:

Zero Pressure Balloon Production

1. Two balloons of volume 23817 m$^3$ fabricated using 26 microns Antrix film as shell for carrying payload weight of 690 kg up to an altitude of 24 km and supplied to Worldview Enterprises, USA.

2. Three balloons of volume 300 m$^3$ fabricated using 10 microns Antrix film as shell for BATAL campaign. These balloons are designed and fabricated to carry payload weight of 40 kg atmospheric science payloads to float at 16 km altitude.

3. Two balloons of volume 1187 m$^3$ fabricated using 15 microns Antrix film as shell for BATAL campaign. These balloons are designed and fabricated to carry payload weight of 90 kg atmospheric science payloads to float at 17 km altitude.

4. Four balloons of volume 3026 m$^3$ fabricated using 15 microns Antrix film as shell for BATAL campaign. These balloons are designed and fabricated to carry payload weight of 60 kg atmospheric science payloads to float at 26 km altitude.

5. A balloon of volume 3026 m$^3$ fabricated using 15 microns Antrix film as shell for Project APEIRO of BITS, Goa.

6. Two balloons of volume 143396 m$^3$ fabricated using 20 microns Antrix film as shell and 30 microns Antrix film as cap for TIFR Infra-red Astronomy experiment.

Tethered Balloons

1. Oblate Spheroid balloon: 30 oblate spheroid balloons of volume ranging from 10 to 85 m$^3$ were fabricated using 76 microns (2 layers of 38 microns) Antrix film as shell for ISAC-ISRO, Bengaluru. Two oblate spheroid balloons of volume 78 m$^3$ were designed and fabricated using 76 microns (2 layers of 38 microns) Antrix film as shell for testing of various communication and surveillance equipment of IIT-Bombay with a payload weight of 45 kg up to an altitude of 100 meter.

2. Sounding balloon: 25 sounding balloons of volume 4077 m$^3$ were fabricated using 5.5 microns Antrix film as a shell for ISRO-SHAR, Sriharikota.
Balloon Flights and Recovery Operations

Nine main balloon flights were conducted during the reporting period. Details are as follows:

1. **Flight No-491**: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-ZF1) was conducted using a balloon of volume 300 m³ fabricated using 10 microns Antrix film as shell. This flight was successfully launched on 09th August 2017 at 02:56 hrs (IST) with a total suspended payload weight of 52.9 kg including 12 kg ballast powder. The atmospheric science payload consisted of Impactor, COBALT, Ozone-sonde. The balloon reached its maximum altitude of 15.79 km at 03:57 hrs (IST). The balloon was floated for 1 hr 20 min between 15.3 to 15.7 km. The float was controlled by dropping small quantities of ballast and maintained to float in that region. This is the first time we controlled the zero pressure balloon by dropping the ballast at very low altitudes in upper tropospheric temperature region of -71 deg C. After successful experiment, the flight was terminated at 05:03 hrs (IST) using a programmable timer. All the sub-systems worked well during the flight. The payload was recovered from 290 km west of TIFR Balloon Facility.

2. **Flight No-492**: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-ZF2) was conducted using a balloon of volume 300 m³ fabricated using 10 microns Antrix film as shell. This flight was successfully launched on 16th August 2017 at 01:49 hrs (IST) with a total suspended payload weight of 57.0 kg including 15 kg ballast powder. The atmospheric science payload consisted of Impactor, COBALT and Ozone-sonde. The balloon reached its maximum altitude of 16.86 km at 02:29 hrs (IST). The balloon was floated for 20 min at around 14.8 km and again after dropping ballast the balloon ascended to 16.8 km and floated for 70 min. After successful experiment, the flight was terminated at 03:45 hrs (IST) by using a programmable timer. All the sub-systems worked well during the flight. The payload was recovered from 359 km north west of TIFR Balloon Facility.

3. **Flight No-493**: Balloon-borne experiment for Asian Tropopause Layer (BATAL-HF1) was conducted using a balloon of volume 3,026 m³ fabricated using 15 microns Antrix film as shell. This flight was successfully launched on 18th August 2017 at 01:56 hrs (IST) with a total suspended payload weight of 73.6 kg. The atmospheric science payload consisted of MCPC, Boulder counter, Optical Particle Counter, COBALT, Radio-sonde, Frost Point Hygrometer. The balloon reached its maximum altitude of 27.3 km at 03:11 hrs (IST). After successful experiment, the flight was terminated at 03:26 hrs (IST) using a pre-set timer. All the sub-systems worked well during the flight. The payload was recovered from 158 km south west of TIFR Balloon Facility.

4. **Flight No-494**: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-ZF3) was conducted using a balloon of volume 300 m³ fabricated using 10 microns Antrix film as shell. This flight was successfully launched on 22nd August 2017 at 01:28 hrs (IST) with a total suspended payload weight of 62.0 kg including 18 kg ballast powder. The atmospheric science payload consisted of Impactor, Optical Particle Counter, COBALT, Radio-sonde and Ozone-sonde. The balloon initially reached 14.4 km at 02:18 hrs (IST) and started floating. After dropping 8 kg of ballast (four intervals of 2 kg) to push the balloon to 15 km and 1 kg ballast in an interval of 15 min, the balloon reached its maximum altitude of 16.2 km at 04:50 hrs (IST). A duration of 2 hr 45 min float was provided to the experimenter. After successful experiment, the flight was terminated at 05:00 hrs (IST) using a pre-set timer. All the sub-systems worked well during the flight. The payload was recovered from 228 km north west of TIFR Balloon Facility.

5. **Flight No-495**: Balloon-borne experiment for Asian Tropopause Layer (BATAL-HF2) was conducted using a balloon of volume 3,026 m³ fabricated using 15 microns Antrix film as shell. This flight was successfully launched on 24th August 2017 at 01:33 hrs (IST) with a total suspended payload weight of 75.2 kg. The atmospheric science payload consisted of MCPC, Boulder counter, Optical Particle Counter, COBALT, Radio-sonde and Frost Point Hygrometer. The balloon reached its maximum altitude of 26.9 km at 02:52 hrs (IST). After successful experiment, the flight was terminated at 03:15 hrs (IST) using a pre-set timer. All the sub-systems worked well during the flight. The payload was recovered from 196 km south west of TIFR Balloon Facility.
During this campaign, four-rubber balloons were also launched for carrying BATAL experiments.

6. **Flight No-496**: Infra-red Astronomy flight was conducted using a balloon of volume $1,43,396 \text{ m}^3$ fabricated using 20 microns Antrix film as shell and 30 microns Antrix film as cap. A balloon carrying a TIFR far-infrared 100 cm telescope (T100) payload weighing 845.5 kg was successfully launched on 30th November 2017 at 22:15 hrs (IST) from TIFR Balloon Facility. The balloon reached its ceiling altitude of 31.7 km after 2 hrs 22 mins with an average ascent rate of 223 m/min. The telescope was allowed to float for 5 hrs 52 mins for experimental observations and the flight was terminated at 06:30 hrs (IST) using a programmable timer. The payload was recovered from 170 km north-west of TIFR Balloon Facility.

7. **Flight No-497**: The balloon-borne experiment for the testing of micro satellite developed by the BITS Goa students under the “Project APEIRO” was conducted using a zero pressure balloon of volume $3026 \text{ m}^3$ made using 15 micron Antrix film as shell. The balloon was successfully launched on 02nd February 2018 at 02:12 hrs (IST) which carried a total suspended load of 65.4 kg including 25 kg ballast powder. The balloon reached its first ceiling altitude of 24.8 km in 1 hr 19 mins and floated for one hour and reached its second ceiling altitude of 26.7 km by dropping 25 kg ballast in intervals and allowed to float for 30 mins. This is the first time a zero pressure balloon floated at two different float altitudes. The APEIRO payload consisted of 3-stage Cosmic rays detector functioned as designed. A new altitude encoder also tested in this balloon flight up to 44,800 feet. After successful mission, the flight was terminated at 05:17 hrs (IST). The payload was recovered from 350 km south-west of TIFR Balloon Facility.

8. **Flight No-498**: Balloon-borne experiment for Asian Tropopause Aerosol Layer (BATAL-ZF-HYBRID) was conducted using a special designed and fabricated balloon of volume $1186 \text{ m}^3$ using 15 microns Antrix film as shell. This flight was successfully launched on 10th February 2018 at 02:19 hrs (IST) which carried a total suspended payload weight of 124.8 kg including 10 kg ballast powder. The atmospheric science payloads of ISRO-NASA-CNRS consisted of 10 small instruments (Radio-sonde, Ozone-sonde, COBALD, Cloud Particle Sensor (CPS), Cryogenic Frost Point Hygrometer (CFH), Optical Particle Counter (OPC), Boulder Counter, Aerosol Impactor, Light Weight Aerosol Optical Counter and Mixing Cloud Particle Counter (MCPC)) for measuring aerosols at upper troposphere and lower stratosphere (UTLS) region. The balloon reached its maximum altitude of 18.03 km at 03:15 hrs (IST). The balloon was floated only for 30 min and terminated at 03:42 hrs (IST) by using timer. All the sub-systems worked well during the flight. The payload was recovered from 171 km north-east of TIFR Balloon Facility.

9. **Flight No-499**: Infra-red Astronomy flight was conducted using a zero pressure balloon of volume $1,43,396 \text{ m}^3$ fabricated using 20 microns Antrix film as shell and 30 microns Antrix film as cap. Balloon carrying a TIFR far-infrared 100 cm telescope (T100) payload weighing 856.5 kg was successfully launched on 18th March 2018 at 21:41 hrs (IST) from TIFR Balloon Facility. The balloon reached its ceiling altitude of 31.5 km after 1 hr 51 mins with an average ascent rate of 284 m/min and was allowed to float for 5 hrs 35 mins for experimental observations and terminated at 05:07 hrs (IST) using tele-command. The payload was recovered from 350 km south-west of TIFR Balloon Facility.

All the above nine flights were successful in all aspects.

**Tethered Balloons Hoisting**

The following balloons with specifications as detailed below were custom designed for different experiments and fabricated at Balloon Facility during the reporting period:

1. **Rubber balloons**: Three rubber balloons were launched from Balloon Facility to study the upper wind pattern during the scientific experiments.

2. **Kytoons**: TIFR Balloon Facility successfully hoisted colored kytoon of volume of 9.9 $\text{ m}^3$ with GPS radiosonde using motorized electrical winch at Khodad, Pune on the Science Day-2018 programs of NCRA-GMRT.
Recent Developments in Balloon Support Instrumentation and Research Group

This group is mainly involved in the design, development and testing of balloon control instrumentation to minimize the mass and power requirements and for air-safety. A summary of major works carried out during the reporting period is listed here:

**TM/TC package:** Consolidated and froze the configuration of all the onboard sub-systems namely: telemetry, tele-command, GPS, ATC transponder, GSM-GPS system, batteries and antennas as one loadline package (12 kg) that helped to make the package quickly for all the BATAL flights and the BITS Goa student flight. In addition, a small Ballast CAN was designed that could be hand-launched as a separate package with about 20kg ballast and controlled and separated from command by 10 m loadline cable.

**BATAL flights:** Support provided to all BATAL flights conducted during monsoon (2017) and winter (2017/2018) by arranging Lithium-ion rechargeable batteries (30V, 11A) and lithium Polymer (12V, 5.5AH) batteries to the atmospheric science instruments which are very crucial for the experiment. In addition, the experimenter had only two receiving stations but the transmissions were on 4 different frequencies. Therefore, we installed two receiving stations (IMET) for their data acquisition and storage, thus making their mission successful.

**Air-Safety:** Mode-S transponder has been procured and tested with its Test equipment (IFR 6000) and is found to be working well. To use it, we have to get a 24 bit unique address from DGCA New-Delhi. The process has been initiated. We have upgraded the upper operating altitude of the Altitude encoder (from 30000ft to 45000ft). In all the 3 flights that it was used, it worked well thus improving air-safety.

**New Telemetry scheme:** In order to meet the requirements of the IR flight with new detector, we propose two carrier frequencies (2259 MHz and 2281 MHz) for the two telemetry data (one at 10kbps and the other at 250kbps). We tested this scheme and found that it’s a workable solution with two receiving chains and a common Dish antenna. The transmitter at 2281 MHz has frequency stability problem at higher temperatures which can be rectified using suitable crystal and test-select few components. The work is in progress.

**FPGA based onboard decoder:** The tele-command encoder and decoder was implemented on a commercial development board and tested successfully. A circuit and PCB design specific to the application was made and fabricated. Good quality components and FPGA has been procured. Components need to be populated and the design to be validated on the actual board (10cm x10 cm).

**Data Monitoring from Various Instruments for Atmospheric Science Study**

This group has been involved in research activities by using the data obtained from different instruments deployed at Balloon Facility as part of National network of ISRO-GBP namely, ARFI-SPL-VSSC Trivandrum, ATCTM-PRL Ahmedabad, etc. The data monitored from various instruments under these projects are also shared between Balloon Facility and the collaborating institutions. We also collaborated and provided extensive support to the scientific teams of several national and international academic and research institutes namely NPL New Delhi, PRL Ahmedabad, NARL Gadanki, IMMT–CSIR Bhubaneshwar and NASA-LaRC, Hampton, VA, of USA, for designing balloon experiments and interpretation of data that led to several joint publications.

**Status Report on Workshop, Civil & Electrical Group**

The workshop group has been assigned several responsibilities such as fabrication of payload gondola, mechanical integration of flight packages, hydrogen gas readiness for flights, making machined components, maintenance of electrical supply to the campus, generators, air conditioners, LAN Network, cable network, telephones lines, Surveillance cameras, CCTV cameras and bio-metric attendance system. In addition, the field illumination, portable generator and standby power are also arranged during every balloon flight. This group also looks after day-to-day civil and general maintenance work of existing infrastructure at Balloon Facility. A summary of major works carried out during the reporting period is listed here:

1. Payload gondola was made for BATAL, Project APEIRO experiments of BITS Goa.
2. Fabricated bottom end fittings (M-27) (3 Nos.) and top end fittings of diameters 685 mm (1 No).
3. Nylon bottom end fitting (60 Nos.), destructive device (Aluminum) (5 Nos.) and Acrylic (6 Nos.)
were made.

4. Completed major work such as water proofing in all old buildings (Balloon building, CIBA building, old hostel, electrical and store rooms and canteen service area), refurbishment of conference hall stage and canteen cooking area, minor civil repairing and painting work in the Balloon Facility premises.

5. Completed general servicing of all shutters doors of hydrogen shed and balloon building.

6. Repaired plumbing lines of old hostel rooms, balloon building, canteen, ECIL water line and also replaced some faulty parts with new ones in the Balloon Facility premises.

7. Line protection circuit installed in the server room for EPBAX system protection.

8. Replaced timer unit for 200 KVA generator.

9. Installed LED lights in VIP guest rooms, old hostel rooms, field illumination and also replacing all regular illumination with LEDs.

10. General electrical maintenance and periodical servicing of ACs.

11. Day-to-day monitoring of various parameters related to ILGTTI-HPC project.

Members

Scientific and Technical


Administration and Auxiliary


National and International Involvement

Tropical Tropopause Dynamics Experiment

As a part of collaborative research project between SPL-VSSC and TIFR Balloon Facility under Tropical Tropopause Dynamics (TTD) experiment, 19 rubber balloon flights were conducted from Balloon Facility between April 2014 and September 2017 using Cryogenic Frost-point Hygrometer, Ozonesonde and GPS radiosonde, to investigate the vertical distributions of water vapor, ozone along with other meteorological parameters in the upper troposphere and lower stratosphere (UTLS) region.

Balloon borne study of Asian Tropopause Aerosol Layer (BATAL) program

Atmospheric aerosols (micron size particles) and clouds play a critical role in earth weather and climate system are also the major source of uncertainties for future climate projection. Recent Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) discovered that these aerosols form a layer like blanket in the tropopause layer in the Asian region and so called “Asian Aerosol Tropopause layer (ATAL)”. This is of major concern since this layer occurs between 16-18 km from the earth’s surface during active monsoon (June-August) over anti-cyclonic region stretches from the east Mediterranean sea to west China. To understand this enigmatic layer, balloon borne experiments along with ground-based observations were conducted over Hyderabad under ISRO-NASA-NARL-TIFR-BF during August 2017-February 2018 under collaborative program called “Balloon Borne measurement campaigns of Asian Tropopause Aerosol Layer (BATAL)”.
Non-DAE Research Projects

D.K. Ojha, P.R. Sinha and B. Suneel Kumar
Aerosol Radiative Forcing over Hyderabad and its impact on Mega city climate under ISRO-GBP-ARFI, 2007-2017

D.K. Ojha, P.R. Sinha and B. Suneel Kumar
Long term measurement of Ozone, NOx, SO2 and total solar radiation at a remote site to study the emission fluxes and change in their concentrations. (in collaboration with IICT Hyderabad)
Low Temperature Facility

Low Temperature Facility provides liquid helium, liquid nitrogen and cryogenic support services to various facilities and laboratories of the institute. The primary function of LTF is to meet the cryogen demands of various research facilities of the institute. Helium gas is liquefied with the Linde make, Model-L280 helium liquefier (installed in the year 2008) and Liquid nitrogen from Stirling Cryogenics make, Model: STIRLIN-8 liquid nitrogen plant (installed in the year 2010).

Liquid Helium

A total of 1,08,236 liters of liquid helium was consumed by various users of the institute during the report period, which is about 0.8% higher than that of last financial year. LTF handles largest numbers research users in India supporting various / critical helium setups within TIFR. During the report period, LTF dispensed more than 900 liquid helium dewars to the users, which is 8% higher than that of previous year. Our helium gas loss rate was reported at 14.5% with two known major incident as draining of 5000 liters mother dewar for flushing and failure of recovery balloon level controller timing belt resulting in leakage through its relief valve. As a part of controlling the helium gas loss, Mr. K A Jaison initiated the leak testing of helium recovery line / manifolds at various laboratories which includes labs at room #AB94, AB81, AB83, CG21, CG24, CG27, P106 and W139. Leak testing of remaining labs are currently in progress. A major helium gas leak noticed at the old and rusted steel recovery pipeline at pelletron block was successfully rectified with modified copper piping. Figure shows the repair of recovery line modification done at Pelletron block. Continuous safety measures are taken to avoid such gas loss in future with suitable provisions.

Annual Preventive Maintenance of L280 Helium Liquefier
The annual preventive maintenance of L280 helium liquefier and plant decontamination carried out during the report period in-house by LTF. The maintenance schedule worked out without affecting the regular user dispensation.

Miscellaneous works on helium liquefier
1. Replacement of faulty instrument air piping of L280 helium liquefier
2. Preventive maintenance of high-pressure helium recovery compressors #1 & #2 carried out successfully.
3. Repair of faulty water flow switch for turbine cooling of Helium Liquefier

**Liquid Nitrogen**

To cater the institute’s liquid nitrogen demands, LTF consumed about 2,62,593 liters of liquid nitrogen in this year, which is about 14% higher than the previous year. The nitrogen plant produced about 72,700 liters and in order to compensate the regular demands of nitrogen supply, LTF procured about 1,89,893 liters of liquid nitrogen from external sources. About 50 liquid nitrogen dewars were kept in regular service to facilitate various nitrogen users within the institute.

**Maintenance of STIRLIN-8 liquid nitrogen plant (September 2017)**

The annual preventive maintenance of the STIRLIN-8 liquid nitrogen plant carried out successfully during 21 – 25 September 2017. The annual preventive maintenance job includes Servicing of both Cryogenerator and its components such as Cleaning of condenser Head, Regenerators, Water Cooler, Displacer etc. Settings of all the valves and limit switches verified. The preventive maintenance includes the servicing of air compressor, air drier unit, chiller line etc. Plant restarted after maintenance and all the parameters and functionality check found to be normal.

**Developmental Activities in Cryogenics**

During the report period, LTF actively taken up many cryogenic developmental activities as college projects mentioned as below.

1. Design and Development of double walled vacuum-jacketed Liquid Nitrogen piping (BE Project-VIIT, Pune)
2. Theoretical analysis and porosity prediction of Stirling cryocooler regenerator considering the unsteady flow (ME Project-RGIT, Mumbai)
3. Development of mobile based data logging and auto reporting system of Helium Gas flowmeter for LTF (BE Project- RGIT, Mumbai)
4. Analysis and parametric optimization of regenerator for Stirling Cryocooler (ME Project- VJTI, Mumbai)
5. Indigenous development of Stirling cryogenic regenerator using Additive manufacturing (TIFR)

**Cryogenic Support Services**

Besides these main cryogenic plants, LTF also handles and maintains other auxiliary support services such as Mass-Spectrometer-helium-leak-detector (MSLD) and vacuum related services to various users whenever required. LTF successfully carried out the mandatory HST testing of six high-pressure helium gas quads (four quads of LINAC and two of LTF) along with few loose cylinders. The tested gas quads and cylinders brought back to service after leak testing, evacuation and purging for safe helium use. LTF carried out the repair and revival of c4 and C5 lightweight aluminium alloy liquid helium dewar. We also successfully repaired the heavily damaged 200L liquid helium aluminum dewar during its road transport to TIFR Hyderabad. LTF continue to provide technical assistance in cryogenics related jobs to the various laboratories/departments of the institute whenever required.

**Work carried out at TCIS (FreTb Campus) Hyderabad**

*Installation new Recovery line for NMR at FreTb campus (June 2017):* Mr.Vijay Arolkar provided technical assistance in carrying out the installation and commissioning of helium recovery line at newly established FreTb campus during June 2017. The job includes the laying of 2” SS pipe, 1 5/8” copper pipe with the laboratories along with safety valve, valve manifold, pressure gauge, check valve, shutoff valves etc.

*Installation new Recovery system at FreTb Campus (October 2017):* The new helium recovery compressor, gasbag, helium gas manifold and helium gas collecting quad was shifted from TCIS transit campus to the newly constructed FreTb campus. The entire recovery system successfully installed & commissioned with active technical support by Mr. Sandal & Mr.Arolkar.

*Repair and re-evacuation of liquid nitrogen dewars: Three non-functional liquid nitrogen dewars at TCIS Hyderabad were successfully repaired and revived by Mr. Arvind Hedukar.*

**Technical Assistance to other institutions**

LTF provided technical help and assistance towards the installation of a Helium plant, and the laying of recovery lines in our experimental physics block for Indian Institute of Science Education and Research (IISER), Pune during November, 2017.

LTF also provided technical assistance for the new installation of cryocooler based liquid helium plant and helium gas recovery system for Department of Solid
State Physics, Indian Association for the Cultivation of Science, Jadavpur, Kolkata during November 2017.

Members
V. A. Arolkar, K. A. Jaison, K. V. Srinivasan (Engineer In-charge)

Technical
D. S. Sandal (till 31.10.2017), Bosco Augustine, A. G. Hedukar, D. G. Purao, Nikhil Kumar

National and International Involvement

K. V. Srinivasan
1. Life member in Indian Cryogenics Council
2. Elected member and Treasurer of Indian Cryogenic Council (Western Zone)
3. Advisory member, Department Advisory Committee, Rajiv Gandhi Institute of Technology, Andheri (for assessing the Curriculum Gap and uplift the academic standards of Thermal Engineering, Design Engineering, Manufacturing Engineering and Management subject), Nov. 2017

Visits

K. V. Srinivasan
1. Resource person, Two Days National Level Seminar Workshop on “Advances in Cryogenics and Cryo-Materials” sponsored by Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India, organized by Veltech Dr. R. R. & Dr. S. R. Technical University, Chennai, 10 and 11, November 2017
2. Participated in the Interaction Meeting on Collaborative Activities between TIFR-VIT (Vishwakarma Institute of Technology, Pune) and TIFR, VIT, Pune, January 2018

Invited Talks

K V Srinivasan
1. Thermodynamic review of cryogenic refrigeration cycles in liquefaction of gases. Department of Mechanical Engineering, Navodaya Institute of Technology (NIT) Raichur, Karnataka, 16 Oct 2017
2. Exposure to Industrial Automation & Control. Department of Mechanical Engineering, Navodaya Institute of Technology, Raichur, Karnataka, 16 Oct 2017
4. Presented project proposals in the Project Collaborative Meeting with Vishwakarma Institute of Technology, Pune and TIFR, Mumbai, September 2017
National Facility for High Field NMR

Unfolding mechanism of mitochondrial Cyclophilins (CPR3) from Saccharomyces cerevisiae

Cyclophilin catalyzes the ubiquitous process, “peptidyl-prolyl cis-trans isomerization” which plays a key role in protein folding, regulation and function. Cyclophilins are expressed in all organisms including prokaryotes and eukaryotes in various varieties which are different in their size and localization. Even though, several structures of the cyclophilins from different organisms are available in both ligand bound and free forms, however the folding and unfolding pathways of cyclophilins are poorly understood. We report here detailed characterization of the unfolding of yeast mitochondrial cyclophilin (CPR3) induced by urea. It is seen that CPR3 unfolding is reversible and proceeds via two intermediates, I1 and I2. The I1 state has native like secondary structure and shows strong ANS binding due to increased exposure of solvent accessible cluster of non-polar groups. Thus, it has some features of molten globule. The I2 state is more unfolded, but retains some residual secondary structure, and shows weak ANS binding. Chemical shift perturbation analysis (CSP) by 1H-15N heteronuclear single quantum coherence spectra reveals disruption of the tertiary contacts among the regions close to the active site in the first step of unfolding, i.e. N-I1 transition. Regions showing high CSPs in the N-I1 transition match with the regions showing high RMSD in the NMR structure of protein, which showed the presence of two states (open and closed) in the ensemble. This indicates that I1 state has some structural similarity with the functionally relevant “open state”. Both the intermediates, I1 and I2 showed a propensity to self-associate under stirring conditions, but their kinetic profiles are different; the native protein did not show any such tendency under the same conditions. All these observations could have significant implications for the function of the protein. [Vaibhav Shukla, R.V. Hosur]

Structural characterization of a cataract-active mutant of human γS-Crystallin

Cataract, or opacification of the eye lens, is the leading cause of blindness world over. While age-related cataract is the result of accumulation of environmental and metabolic effects, congenital cataract, seen in newborn children, is essentially genetic in origin. A mutant of human γS-crystallin, G57W, has been recently reported in a Chinese family wherein a young boy and his mother were found to have cataract in the center of the lens. We attempted to structurally characterize the G57W mutant and study its dynamics by solution NMR. In this endeavour, a suite of heteronuclear 2D and 3D NMR experiments with uniformly 13C/15N-labelled γS-G57W has enabled almost complete sequence-specific 1H, 13C and 15N resonance assignments. Unfolding kinetics of γS-G57W upon heating and addition of chemical denaturants revealed γS-G57W to be less stable compared to its wild-type. Efforts are on to study the inter-domain interactions in γS-G57W and to understand the mechanism of cataractogenesis, since it is not clear as to how a single-point mutation in γS-crystallin compromises eye lens transparency and packing, and finally causes cataracts. [Jishan Bari, Shrikant Sharma and K.V.R. Chary]

Protein and RNA dynamics using NMR spectroscopy

Understanding the conformational dynamics of T4 Lysozyme L99A

T4 Lysozyme cavity mutants interconvert between two compact on formations however the mechanism of interconversion is remains unknown. Using a combination of MD simulations and NMR spectroscopy we have established that the interconversion proceeds without any large scale disruption of the structure and has a very modest activation barrier of ~5 kBT. We have also established that the molecule acquires the activation energy via interactions with water. We are now trying to understand how water provides the activation energy. RNA molecules like riboswitches interconvert between different states that can large changes in structures which includes changes to in secondary their structure. The mechanism of how these large changes in basepairing etc. occurs is not known. We are trying to address these questions by studying the spliced leader sequence from L. collosma that interconverts between two very different structures. [Pramod Vallurupalli]
Binding studies of neuronal nitric oxide synthase (nNOS) and Dynein Light Chain (DLC1)

nNOS-DLC1 interaction, conformational effects: This project is focused on the binding study of neuronal nitric oxide synthase (nNOS) and Dynein Light Chain (DLC1). The neuronal nitric oxide synthase (nNOS) is an essential enzyme involved in the synthesis of nitric oxide (NO), a potent neurotransmitter. As reported from various research papers DLC1 interacts with nNOS (or other receptors) possibly during its localization, and induces certain structural changes to it. We aim to investigate the impact of DLC1 binding to the nNOS N-terminal peptide (17 kD), that was earlier shown to be involved in DLC1 binding. We have already seen from difference CD spectral studies that the binding of DLC1 (12kD) indeed induces helicity to the otherwise unstructured nNOS peptide (17kD). Earlier pull down assays have supported binding of DLC1 with the nNOS peptide. We also used the co-purification and Gel filtration methods to confirm the binding. The quantum yield of tryptophan fluorescence of nNOS peptide was also found to increase on binding of tryptophan-free DLC1 mutant. However, NMR (HSQC at different ratios of DLC1 to nNOS) could not give any clear indication of binding, suggesting that the binding of DLC1 to nNOS might be predominantly electrostatic in nature with fast exchange equilibrium. [Deepa Jaiswal, P. K. Madhu, S. Mazumdar]

Monitoring the Early Event of Oligomerization of Disordered Amyloid β Peptide

Considerable evidence has indicated that the Alzheimer’s disease (AD) which is a most common and progressive neurodegeneration disease was triggered by neurotoxic assemblies of the Amyloid β (Aβ) peptide. Recent studies have shown that pre-fibrillar structures such as soluble oligomers1–4 of Aβ peptide are key toxic species in AD. In our current investigation, with Aβ (1-40) peptide we have established that the peptide became more helical, ordered and compact in the oligomeric state and both the helical and β-sheet components found to increase significantly in the early state of oligomerization process. The hand-selective-optimized-flip-angle shot-transient (SOFAST)-HMQC 2D NMR measurements suggested that most of the residues in the sequence stretch from 12 to 22 in addition with two other C–terminal residues (32 &34) in Aβ40 peptide possessed strong propensities to acquire ordered secondary structure in the very early event of oligomerization. 2D 15N,1H Heteronuclear correlation spectra of Aβ40 showed poor dispersion (~1.1 ppm) of most of the backbone 1HN resonances and appeared between 7.5–8.4 ppm. Additionally, the line widths were sharp and very slow relaxation in the indirect dimension leads to high acquisition time (t1max), which is typical for unfolded macromolecules, indicating the lack of proper globular fold in Aβ40. In order to monitor the structural heterogeneity and compactness in residue specific manner, we have recorded one set of experiments. [Anupam Roy, Kousik Chandra, Sandip Dolui and Nakul C. Maiti]

Novel Pure Shift NMR Methods and Their Applications

Solution state NMR plays an important role in structural studies of small organic molecule mixtures and proteins. However, more often severely overlapped 1H-1H scalar couplings present in the inherent limited 1H-NMR chemical shift range (~10 ppm) significantly hampers the spectral resolution and that makes the chemical shift analysis difficult. In order to circumvent this issue, different advanced versions of PSYCHE/ ZS-homodecoupling (pure shift NMR) methods have been developed, i.e, NUS-PSYCHE-TOCSY, PS-CLIP-COSY, Hadamard-PSYCHE-TOCSY, CPMG-PSYCHE/ Inversion Recovery (IR)-PSYCHE, for unambiguous chemical shift assignments and to monitor the drug-protein interactions. Additionally, for the simultaneous determination of 1H-1H and 1H-19F scalar couplings in complex steroid molecules, a homodecoupled diagonal-2D experiment, F1-PSYCHE-DIAG has also been developed. On the other hand, to recover the homonuclear scalar coupling information that decouples in the pure shift NMR, two different variants of pulse sequences, viz., selective coupling reintroduction in pure shift (SCRPS) and J-scaled pure shift (JSPS) experiments are designed; wherein, the earlier one maps complete scalar coupling spin network of complex organic molecules and the latter one facilitates the measurement of valuable long range scalar coupling information at ultra-high
resolution. The applications of pure shift NMR methods are not only limited to small molecules, and they have been extended for the sequential acquisition of two HSQC spectra (13C-HSQC of small molecules and 15N-HSQC of proteins) in a single NMR experiment (PRO-SMASH-HSQC2). This method permits monitoring the drug-protein interactions at atomic levels and will have a potential applications in drug discovery programs. [Veera Mohan Rao K. and R. V. Hosur]

Development of a prototype for standardization of crude extracts using the anti-diarrhoeal activity of the hydroalcoholic extract of Psidium guajava (Guava) leaves as an example

Even though guava (Psidium guajava) leaves are globally used as an anti-diarrhoeal, the functional components in them largely remain unknown, due to their complex chemical composition and possible synergism involved. The major aim of the study is to develop a prototype for standardization of crude extracts using the example of anti-diarrhoeal guava leaf extract (GLE). The study aims to correlate the anti-diarrhoeal activity-related phytoconstituents in GLE with the Nuclear Magnetic Resonance (NMR) spectral data. The NMR profiling was done at the National Facility for high-field NMR, TIFR, Mumbai on a 800 MHz Bruker instrument. A total of 110, proton NMR profiles were recorded and 2-D NMR spectra were also acquired for 6 of these samples. Work was undertaken at the Foundation for Medical Research on 9 bioassays that represent various steps in diarrhoeal pathogenesis. The spectral data generated at TIFR and the bioassay data from FMR is now being correlated using the various techniques like Principle Component Analysis (PCA), Regression Analysis and Orthogonal Partial Least Square-Differential Analysis (OPLS-DA) with different softwares such as MATLAB, SIMCA and TOPSPIN.

This approach would help in identifying signals in the spectrum that code for the activity and in turn help in standardization of the extract. The metabolomics based modern approach of standardization of drugs will not only help modernize traditional medicine but will also help towards better acceptability of these plant based remedies. [Tannaz Birdi (Foundations for Medical Research, Worli)]

NMR in Herbalomics

It is becoming apparent in recent times that herbal medicines are useful for treating a number of ailments, and these have much less side effects compared to their allopathic counterparts. Herbal preparations have many constituents which seem to work in a synergistic manner, and thus a particular preparation is able to cure many seemingly unrelated diseases; presumably, different components of the preparations are responsible for different activities and because of the synergy between them, the side effects are likely to be reduced. We have termed here this area of science dealing with systematic characterization of the effects of variety of herbal preparations, on various metabolic pathways, diseases etc, as ‘HERBALOMICS’. As of now, detailed scientific investigations with proper controls and precise descriptions of the variety of herbal preparations that are being used discretely without proper quantitation by the ‘Ayurvedic Vaidyas’ are lacking, which is why, this line of treatment is yet to receive general acceptance among the medical community. We have initiated a detailed study of various aspects of a variety of herbal preparations using NMR which is the most powerful tool for characterizing structures and interactions of molecules in solution. [Mandar Bopardikar, Kavitha Rachineni, R. V. Hosur]

Design and development of novel sensing strategies for imaging non-genetically encoded small molecules and ions in vivo

The theme of the research group is to use fundamental chemical insights from molecular recognition and coordination chemistry to devise highly sensitive and reversible molecular detection schemes. The overall goal is to apply the probes for elucidating the role of dynamic changes in small molecules and ions in biological function. The probe development efforts heavily rely on the synthesis and characterization of novel compounds. NMR is one of the major characterization techniques used for validating the structures of novel probes. [Ankona Dutta]
Members
D. A. Jadhav, M. V. Joshi, J. K. Malkan, M. V. Naik, Raju Padale

National and International Involvement
K.V.R. Chary
1. Director, Indian Institute of Science Education and Research, Behrampur, 2017-present
2. Council Member, National Academy of Sciences, India, Allahabad, 2016-2018
5. Treasurer and Steering Committee Member, Asian Biophysics Association, 2013-present
6. EC member and Secretary of National Magnetic Resonance Society, India, 2017-present
7. G N Ramachandran Gold Medal for Excellence in Biological Sciences and Technology for the year 2017 instituted by the Council of Scientific and Industrial Research (CSIR)

R.V. Hosur
1. Chairperson, INSPIRE Faculty Selection Committee
3. Academic Board, UoM-DAE CBS, 2009-2017
4. Member, DAE-SRC young scientist award committee
5. Member, NASI young scientist award selection committee
6. Member, NASI Fellowship Scrutiny Committee
8. Member, Council, International Society of Magnetic Resonance (ISMAR 2014-)
9. Member, Scientific Advisory Committee of ISMAR, 2014-
10. Member, DBT task force on Modern Biology, 2014-
11. Elected ISMAR Fellow, 2017

Deepshika Verma
Awarded oral presentation award during Asia-Pacific NMR Conference-2017, IISc Bengaluru, February 16-19, 2017

Conferences Organized by the Research Facility
NMR Meets Materials, Discussion Meeting
TCIS, Hyderabad, May 5-6, 2017
This discussion meeting was organized to bring together material and NMR experts in India, for cross fertilization of ideas.

Emerging Topics in NMR: Discussion Meeting
TCIS, Hyderabad, 25 August 2017
The meeting brought together NMR spectroscopists from different areas of research, ranging from hyperpolarization techniques, material sciences, biophysics, NMR methods and hardware development. The aim was to foster a discussion on the possible implications of work in these fields and their impact on the broader landscape of NMR spectroscopy itself.

TIFR, Hyderabad High Field NMR Facility Symposium
TCIS, Hyderabad, February 13-14, 2018

Non-DAE Research Projects
1. DST-DIIRSRT joint Research Project under Australia-India Strategic Joint Research Fund (AISRF)
2. Indo-French IFCPAR/CEFIPRA project “Novel nanocatalysts synthesis guided by DNP NMR”
The Pelletron LINAC Facility (PLF), a joint project by TIFR and BARC, continued to serve as major facility for research. The facility spent ~ 24% time on maintenance, ~11% time on HV conditioning and beam operations comprised ~ 65%. During this year, a total of 57 experiments were carried out using different beams (H to 37Cl). The research work at the facility has resulted in 31 publications in refereed international journals and 8 Ph.D. theses.

The LINAC was operated during April-May 2017 and March-April 2018 for a total of 20 experiments. In recent times, there has been a growing interest in using heavier ions (28Si and above) with LINAC. Typically, the lifetime of the terminal stripper foils in the Pelletron severely limits the delivery of steady beam with modest intensity (~1–2 pnA) on the target. Moreover, the quality of the foils affects the transverse and longitudinal emittance, and thus hinders the transport and acceleration of such heavy beams through LINAC booster. Hence, it is highly desirable to use the recirculating gas stripper in the terminal. The gas pressure in the stripping canal needed to be optimized for best efficiency and to avoid deterioration of the vacuum in the accelerator tubes. The heavy ions beams 28,30,32S, 32,34,36Cl were delivered using a recirculating gas stripper in the Pelletron terminal section. The typical stripping efficiency has been observed to be between 10–30% and as expected the mean charge state was ~20% lower than that with a foil. However, the distinct advantage was the much lower energy spread and extremely stable operation over several days, leading to a marked improvement in the quality and net intensity of the beam delivered on target. Keeping the future interest for heavier beams, test runs for Ca, Ti, Fe, Ni were carried out with the gas stripper for assessing the yield and acceptance in LINAC for further acceleration. Measurements have shown that Ti beam can be made available to users, while for heavier beams Pelletron operations at higher terminal voltage would be essential.

In order to improve the reliability and accuracy of the RF phase settings, a high precision phase measurement unit has been developed based on the AD8302 phase detector chip. This Analog Device chip can be used up to 2.7 GHz and produces a precisely calibrated output 10 mV/degree over a range of 180°. For reliable measurements over entire 0-180° range, a combination of two chips, with 90° phase shift has been employed. The 90° phase shift is added by using accurately trimmed (<1%) fixed length cable delay for the LINAC operating frequency (150 MHz). For better accuracy, in the edge zones (close to 0 mV and 1800 mV) where the errors are larger due to bandwidth issues, the phase angle measured by one of the chips is used, while for all other angles the average of the angle determined from both the chips are used. Using this method the linearity and accuracy achieved in the measurement of phase is <±1°. Electronics hardware for this measurement system is developed around Silicon Lab module C8051F020. Proper care has been taken while designing the board to provide an almost complete ground plane to avoid cross-interference in the RF signal paths and EMI, and extra low-pass filters in the power lines to eliminate 50 Hz. The phase difference between the RF cavity pick-up and the reference clock is computed in the range 0-360° and shown on the front panel 2*16 big font LCD display.

Initial tests for Local Control Station for RF control using EPICS (Experimental Physics and Industrial Control System), which is based in open source tools, are in progress. The power supply units of all quadrupoles in LINAC have been upgraded to modern, compact air-cooled units (Danfysik model 9100 MPS) and have been working satisfactorily. The beam transport software control system has been modified to integrate the new MPS. The preamplifier unit, designed for BPM and FC readout is modified for high insulation resistance measurement -1 MΩ to 100GΩ, with switchable range. As an additional safety measure, the beam line valves after the switching magnet have been interlocked with hall access doors. Based on the LINAC access control system, a Search and Secure System is designed and fabricated for FRENA, SINP (Kolkata).

The development of digital Low Level RF (LLRF) control system based on SIS8300-L 10 channel μTCA Digitizer card is in progress. This card has 10 channels of 16 bit ADCs, 2 channels of 16 bit DACs and many I/O pins with built in clock synthesizer. We have successfully implemented various components of Self Excited Loop (SEL), namely, digital IQ demodulator, the loop phase shifter, the running average filter, limiter, digital IQ modulator, PID controller for controlling phase/amplitude of the RF signal and the
CORDIC algorithm for the calculation of phase and amplitude using VHDL programming. These algorithms have been tested on Xilinx simulation platform and tests with VHDL programs on FPGA are in progress. A three pneumatic cylinder based press and a high tensile aluminium alloy die, for forming of niobium components, has been assembled. One set of die that will form outer shell of the Nb cavity is designed and has been fabricated in the central workshop from aluminum alloy. Trials are conducted with the die on aluminum and are found to be satisfactory.

A customized high vacuum furnace, designed for surface treatment of Nb Cavities, was installed and commissioned. This is bottom loading, high vacuum, high temperature furnace suitable for our requirement and designed to operate at a maximum of 1200°C. The design was optimized to provide a vertical hot zone of 600 mm diameter and 1000 mm high with a load capacity of 100 kg. The heat shields were optimized to achieve the maximum operating temperature at a modest power of less than 20 kW. A total of 14 layers of radiation shields are employed. Inner layers are made of two each of La-Mo and Mo, and the rest are made of SS310. The PLC system, safety interlocks and the furnace have been fully installed and commissioned. The system achieves a base vacuum better than 5x10^-7 mbar. At the maximum operating temperature of 1200°C, the system consumes only 17.5 kW of heater power.

The Target lab continued to provide excellent support to all users. All setups – electron gun setup, resistive heating setup, DC glow discharge setup and rolling machine are operational. For some targets, the wastage of enriched source material was minimized by modification of the crucible shape. Nearly ~400 targets of different thicknesses were prepared as per user request for experiments at PLF and other facilities. About ~ 400 DLC foils of thickness 4µg/cm² - 10µg/cm², which are used for terminal foil stripper in the Pelletron, were lifted on holders from slides. A dedicated setup for thickness measurement using energy loss method has been installed. This setup was also used for demonstration to undergraduate students.

The new website for the PLF was released this year. This has a provision to maintain a complete user database and online submission of beam time request. Further, on-line radiation safety training has been set up. Several other user requests and record keeping with restricted access is also facilitated.

Periodic maintenance and load test for all the cranes in PLF is carried out as per directions from MHE committee. The facility strives to meet safety regulations laid down by the BARC Safety Council.

Members

**TIFR**


**BARC**


**Health Physicists (BARC)**

Anil Shanbhag

**Pelletron Linac Facility Committee**

R.G. Pillay (Joint Chairperson), A. Saxena (Joint Chairperson, BARC), Vandana Nanal, S. N. Mishra, R. Palit, L. C. Tribedi, Sanjoy Pal (Member Secretary), A. K. Gupta (BARC), B.K. Nayak (BARC), J.A. Gore (BARC), P. Surendran (BARC), Srinivasan (BARC)
Advisors: Dean, NSF (TIFR) and Associate Director, Physics Group (BARC)

Pelletron Linac Programme Implementation Committee

Invited Talks
R.G. Pillay
1. Particle Accelerators for Discovery of Science. SRFSAT 2017, IUAC
TIFR Centres
Astrophysical Relativity

A ‘no-hair’ test for binary black holes

One of the remarkable predictions of general relativity is that a stationary black hole can be fully described by a small number of parameters — its mass, spin angular momentum and electric charge. As a consequence of this “no-hair” theorem, frequencies of the gravitational radiation (quasi-normal modes) from a perturbed black hole are fully determined by these parameters. Thus, the consistency between multiple quasi-normal modes provides a test of the “no-hair” theorem for isolated black holes. Similarly, the gravitational radiation from a binary black hole system is uniquely determined by a small number of parameters, and hence different spherical harmonic modes of the radiation have to be consistent with the same values of this small set of parameters. Thus, the consistency between different modes of the radiation is a powerful test that it emanates from a binary black hole in general relativity. In anticipation of the upcoming gravitational-wave observations, we have formulated such a test and demonstrated its performance on simulated data. [S. Dhanpal, A. Ghosh, A. K. Mehta, P. Ajith and B. S. Sathyaprakash]

Constraining black hole mimickers with gravitational wave observations

LIGO and Virgo have recently observed a number of gravitational wave signals that are fully consistent with being emitted by binary black holes described by general relativity. However, there are theoretical proposals of exotic objects that can be massive and compact enough to be easily confused with black holes. Nevertheless, these objects differ from black holes in having nonzero tidal deformabilities, which can allow one to distinguish binaries containing such objects from binary black holes using gravitational-wave observations. We have investigated the possibility of constraining the parameter space of such “black hole mimickers” with upcoming observations. Employing perfect fluid stars with a polytropic equation of state as a simple model that can encompass a variety of possible black hole mimickers, we showed how the observed masses and tidal deformabilities of a binary can constrain the equation of state. We also showed how such constraints can be used to rule out some simple models of boson stars. [N. K. Johnson-McDaniel, A. Mukherjee, R. Kashyap, P. Ajith, W. Del Pozzo, and S. Vitale]

Gravitational waveforms for black-hole binaries including the effect of subdominant modes

While the dominant mode of gravitational radiation is quadrupolar, subdominant modes can make appreciable contribution to gravitational waves produced by binary black holes with large mass ratios. In a recently completed work, we constructed an analytical waveform family describing gravitational waves from the inspiral, merger, and ringdown of nonspinning black-hole binaries including the effect of several nonquadrupole modes. We first constructed spin-weighted spherical harmonics modes of “hybrid” waveforms by matching numerical-relativity simulations (with mass ratio 1–10) describing the late inspiral, merger, and ringdown of the binary with post-Newtonian/effective-one-body waveforms describing the early inspiral. An analytical waveform family is constructed in frequency domain by modeling the Fourier transform of the hybrid waveforms making use of analytical functions inspired by perturbative calculations. The resulting highly accurate, ready-to-use waveforms are highly faithful for observation of gravitational waves from nonspinning black-hole binaries and are extremely inexpensive to generate. [A. K. Mehta, C. K. Mishra, V. Varma, P. Ajith]
A major review paper surveying the current status of the coupling between active mechanics and biochemical signalling processing involved in developmental pattern formation was published. [P. Gross, K. Vijay Kumar, S. W. Grill]

We also published a study where we obtained exact analytical results for the steady-state probability distributions of run-and-tumble in one-dimensional geometries with and without confining boundaries. [Kanaya Malakar, V. Jemseena, Anupam Kundu, K. Vijay Kumar, Sanjib Sabhapandit, Satya N. Majumdar, S. Redner, Abhishek Dhar]

Collective dynamics in living matter: activity, information flow and populations

Our research program aims to understand the organization and function of living matter using the tools and perspectives of complexity science, disordered systems, statistical mechanics and dynamical systems. We view biological entities as a truly unique state of active, adaptive matter; cells, biological tissues, coordinated animal groups and interacting populations (ecology) are a form of complex material and dynamical system with emergent properties that arise from mechanical, biochemical and socially mediated interactions between individuals.

We pursue this perspective via two complementary approaches:

1. We construct de novo, synthetic mimics of living matter to study the minimal ingredients for self-assembly, computation, feedback, and evolvability. This serves as a kind of synthetic biology from a physical viewpoint and is likely to shed light on early evolution and the transitions therein. The focus is on understanding and duplicating, using synthetic inanimate components, the emergence of specific, quantifiable, and characteristic properties of living matter, rather than understanding how life itself emerges from its basic molecular building blocks. This is an important distinction from in vitro reconstitution approaches that have characterized many biophysical studies. The problem then naturally lends itself to the framework of statistical physics in which the key properties of the organization of living matter may be described.

2. We probe the physical basis of organization in biological systems. This represents a kind of physical biology which will allow us to quantitatively identify the broadly universal features of biological systems, similar to statistical mechanical approaches in physics. The approach is to make careful measurements on well-chosen biological phenomena and to use theories rooted in non-equilibrium statistical physics and dynamical systems to understand the data. Often, the experimental data requires the development of new theoretical ideas.

Our goal is to weave these two threads into a tapestry that captures many essential features of a theory of the organization and dynamics of living matter. [Shashi Thutupalli, Manoj Kumar, Godwin Stephenson, Anupam Singh, Charuansini Gopal Kulkarni, Chittaspandini Gopal Kulkarni, Ashwini Krishna, Vidhya Lakshmi, Shashwat Kumar, Chandan Reddy, Kushal Applineni, Aniruddh Murali]

Fluid dynamics and Turbulence

Drops and bubbles in two-phase flow

There is an important open question in cloud evolution on how cloud droplets grow so rapidly into raindrops. Jason Picardo, with Samriddhi Sankar Ray and S Ravichandran obtained indirect evidence for our analytical findings on caustics from three-dimensional simulations of particles in turbulence. S Ravichandran completed his PhD on this topic. We had started work earlier on the question of whether small droplets can alter the future of large turbulent structures. We were able to show this is a model two-dimensional flow (Journal of Fluid Mechanics, 2017, with S Ravichandran). We explained the mechanism (Physical Review Fluids, 2017, with Harish Dixit and S Ravichandran) of modification of turbulence (see figure) in buoyant vortices: by the production of baroclinic torque and by magnus lift. With Kirti Sahu, Premalatha and Manoj Tripathi (Physical Review Fluids, 2017) we showed that two bubbles rising in quiescent fluid display interactive dynamics due to wake
forcing. The work on hypersonic flows was completed and formed the thesis of Bijaylakshmi Saikia in IIT Bombay.

Instabilities in stratified and rotating flows

Sharath Jose completed his PhD on this topic. Given his findings (see figure, with Vishnu and Pier, Physical Review Fluids, 2017) on instabilities in rotating shear flow, we asked why the critical Reynolds number is a sensitive function of the rotation number, and showed that this is due to the strong nonnormality in the system (a counter-intuitive finding). Jose also finds (with collaborators) that in viscosity-stratified channel flow, the linear optimal perturbations leading to turbulence lie on the other side of the channel centerline from the dominant nonlinear structures in the fully developed regime. Ongoing work is directed at understanding this result on the basis of nonlinear optimals. Ritabrata Thakur, a PhD student, continued our collaboration well with Jim Moum and Emily Shroyer in Oregon State University. We found a completely surprising suppression of turbulence during late monsoon in the Bay.

Fluid-structure interactions

In collaboration with Narayanan Menon from the University of Massachusetts, and Rajalakshmi from TIFRH, Sumit Birwa showed (Physical Review Fluids, 2018) that a solid sphere approaching a bottom plate at finite velocity through a viscous fluid makes physical contact with the plate before bouncing, whereas shallow water theory suggests that this will not happen (see figure). Work on flexible filaments on 3D geometries, on interactions between falling disks, and on settling of porous objects is nearing completion.

Indian Monsoon

This is a collaboration with Amit Apte, Vishal Vasan and Sreekar Vadlamani. The Markov Random Field approach to describing the monsoon yielded successful first results. It was shown that ten spatial patterns over the Indian landmass are sufficient to describe the rainfall in 95 percent of all monsoon days in the past 110 years. The transition matrices between these patterns enables a further classification into three families. The paper is under revision for resubmission to Dynamics and Statistics of the Climate System, an OUP Journal. The finding opens up several possibilities to understand the dynamics, and these are now being explored.

Modelling Spheroids in Turbulence

We study the rotational dynamics of inertial discs and rods in three-dimensional, homogeneous isotropic turbulence. In particular, we show for the first time how the alignment and the decorrelation time scales of such spheroids depend, critically, on both the level of inertia and the aspect ratio of these particles. These results illustrate the effect of inertia – which leads to a preferential sampling of the local flow geometry – on
the statistics of both discs and rods in a turbulent flow. Our results are important for a variety of natural and industrial settings where the turbulent transport of asymmetric, spheroidal inertial particles is ubiquitous. [A. Gupta, A. Roy, S. S. Ray]

**Deformation and Break-Up Of Droplets in Turbulence**

The statistics of the deformation and breakup of neutrally buoyant sub-Kolmogorov ellipsoidal drops is investigated via Lagrangian simulations of homogeneous isotropic turbulence. The mean lifetime of a drop is also studied as a function of the initial drop size and the capillary number. A vector model of drop previously introduced by Olbricht, Rallison & Leal [J. Non-Newtonian Fluid Mech. 10, 291–318 (1982)] is used to predict the behaviour of the above quantities analytically. [D. Vincenzi, S. S. Ray]

**Non-intermittent Turbulence: Chaos and Irreversibility**

Turbulent flows are special examples of extended dynamical systems distinguished by their intermittent, chaotic and irreversible behaviour. However the exact nature of the effect of intermittency on the chaotic nature of turbulence, and vice versa, is still not known. By using a recent discovery [U. Frisch, A. Pomyalov, I. Procaccia, and S. S. Ray, Phys. Rev. Lett. 108, 074501, (2012)] of Fourier decimation, we manipulate the non-linearity to try and isolate the origins of intermittency, chaos, and irreversibility in homogeneous, isotropic turbulence. In particular, we show, surprisingly, that within the Lagrangian framework it is possible to have non-intermittent, yet chaotic, turbulent flows, with an emergent time-reversibility as the effective degrees of freedom are reduced through decimation. These results suggests a new microscopic way, starting from the equations of motion, of understanding turbulence beyond what is possible through phenomenological models. [Samriddhi Sankar Ray]

**Equilibrium Solutions of the SABRA shell model**

We revisit the two-dimensional SABRA model, in the light of recent results of Frisch et al. [Phys. Rev. Lett. 108, 074501 (2012)] and examine, systematically, the interplay between equilibrium states and cascade (turbulent) solutions, characterised by a single parameter b, via equal-time and time-dependent structure functions. We calculate the static and dynamic exponents across the equipartition as well as turbulent regimes which are consistent with earlier studies. Our results indicate the absence of a sharp transition from equipartition to turbulent states. Indeed, we find that the SABRA model mimics true two-dimensional turbulence only asymptotically as b → −2. [R. Tom, S. S. Ray]

**OTOC in a Classical Spin Chain**

We find that localised perturbations in a chaotic classical many-body system—the classical Heisenberg spin chain—spread ballistically with a finite speed and little change in form as a function of distance from the origin of the perturbation even when the local spin dynamics is diffusive. We study this phenomenon by shedding light on the two complementary aspects of this butterfly effect—the rapid growth of perturbations and its simultaneous ballistic (light-cone) spread, as characterised by the Lyapunov exponents and the butterfly speed respectively. We connect this to recent studies of the out-of-time-ordered correlator (OTOC), which have been proposed as an indicator of chaos in a quantum system. We provide a straightforward identification of the OTOC with a correlator in our system and demonstrate that most of the interesting qualitative features— with the exception of the physics of entanglement— are present in the classical system. We present mostly results for the infinite temperature case but also discuss finite temperatures, where our results remain valid. [S. S. Ray, A. Das, S. Chakrabarty, A. Dhar, A. Kundu, R. Moessner, D. Huse, S. Bhattacharjee]

**Condensed Matter and Statistical Physics**

**Electric response of quantum spin liquid**

We study the coupling between conventional (Maxwell) and emergent electrodynamics in quantum spin ice, a 3+1-dimensional U(1) quantum spin liquid. We find that a uniform electric field can be used to tune the properties of both the ground state and excitations of the spin liquid. In particular, it induces emergent birefringence, rendering the speed of the emergent light anisotropic and polarization-dependent. A sufficiently strong electric field triggers a quantum phase transition into new U(1) quantum spin liquid phases, which trap emergent electric π fluxes. The flux patterns of these new phases depend on the direction of the electric field. Strikingly, some of the canonical pinch points in the spin structure factor, characteristic of classical spin ice, emerge near the phase transition, while they are absent
in the quantum spin liquid phases. Estimating the electric field strength required, we find that this transition is potentially accessible experimentally. Finally, we propose a minimal mechanism by which an oscillating electric field can generate emergent radiation inside a quantum spin ice material with non-Kramers spin doublets. [Etienne Lantagne-Hurtubise, Subhro Bhattacharjee (ICTS-TIFR), and R. Moessner]. A follow up of this work is currently near completion which examines similar effect in experimentally relevant breathing pyrochlores where the system lacks inversion symmetry. Due to the lack of symmetry the contributions to polarisations are different and lead to qualitatively different signatures in the spin correlation function. The critical behaviour of polarisation is also being investigated across a quantum phase transition between the above U(1) QSL and a paramagnet. The transition is driven by breathing anisotropy. [P. V. Sriluckshmy, Ipsita Mandal, Subhro Bhattacharjee, and Roderich Moessner]

**Dynamics of a quantum spin liquid beyond integrability: The Kitaev-Heisenberg-Γ model in an augmented parton mean-field theory**

We present an augmented parton mean-field theory which (i) reproduces the exact ground state, spectrum, and dynamics of the quantum spin-liquid phase of Kitaev’s honeycomb model, and (ii) is amenable to the inclusion of integrability breaking terms, allowing a perturbation theory from a controlled starting point. Thus, we exemplarily study dynamical spin correlations of the honeycomb Kitaev quantum spin liquid within the K −J −Γ model, which includes Heisenberg and symmetric-anisotropic (pseudodipolar) interactions. This allows us to trace changes of the correlations in the regime of slowly moving fluxes, where the theory captures the dominant deviations when integrability is lost. These include an asymmetric shift together with a broadening of the dominant peak in the response as a function of frequency, the generation of further-neighbor correlations and their structure in real and spin space, and a resulting loss of an approximate rotational symmetry of the structure factor in reciprocal space.

We discuss the limitations of this approach and also view the neutron-scattering experiments on the putative proximate quantum spin-liquid material α-RCl3 in the light of the results from this extended parton theory. [Johannes Knolle, Subhro Bhattacharjee and Roderich Moessner]

**Light-cone spreading of perturbations and the butterfly effect in a classical spin chain**

We find that localised perturbations in a chaotic classical many-body system— the classical Heisenberg spin chain – spread ballistically with a finite speed and little change in form as a function of distance from the origin of the perturbation even when the local spin dynamics is diffusive. We study this phenomenon by shedding light on the two complementary aspects of this butterfly effect– the rapid growth of perturbations and its simultaneous ballistic (light-cone) spread, as characterised by the Lyapunov exponents and the butterfly speed respectively (see figure). We connect this to recent studies of the out-of-time-ordered correlator (OTOC), which have been proposed as an indicator of chaos in a quantum system. We provide a straightforward identification of the OTOC with a correlator in our system and demonstrate that most of the interesting qualitative features – with the exception of the physics of entanglement – are present in the classical system. We present mostly results for the infinite temperature case but also discuss finite temperatures, where our results remain valid. [Avijit Das, Saurish Chakrabarty, Abhishek Dhar, Anupam Kundu, David A. Huse, Roderich Moessner, Samriddhi Sankar Ray, Subhro Bhattacharjee]

**Anomalous dispersion of microcavity trion-polaritons**

The strong coupling of excitons to optical cavities has provided new insights into cavity quantum electrodynamics as well as opportunities to engineer nanoscale light matter interactions. Here we study the interaction between out-of-equilibrium cavity photons

![The ballistic spread spread of the cross correlator (classical OTOC) in a Heisenberg spin chain at infinite temperature with butterfly velocity—a demonstration of butterfly effect in magnetic systems.](image-url)
and both neutral and negatively charged excitons, by embedding a single layer of the atomically thin semiconductor molybdenum diselenide in a monolithic optical cavity based on distributed Bragg reflectors. The interactions lead to multiple cavity polariton resonances and anomalous band inversion for the lower, trion-derived, polariton branch – the central result of the present work. Our theoretical analysis reveals that many-body effects in an out-of-equilibrium setting result in an effective level attraction between the exciton-polariton and trion-polariton accounting for the experimentally observed inverted trion-polariton dispersion. Our results suggest a pathway for studying interesting regimes in quantum many-body physics yielding possible new phases of quantum matter as well as fresh possibilities for polaritonic device architectures. [S. Dhara, C. Chakraborty, K. M. Goodfellow, L. Qiu, T. A. O’Loughlin, G. W. Wicks, Subhro Bhattacharjee, and A. N. Vamivakas]

An introduction to Quantum Spin Liquids

Quantum spin liquids represent phases of condensed matter that fall beyond the paradigm of Landau’s symmetry based classification. They, instead, are characterized by the presence of subtle patterns of long-range many-body quantum entanglement. An ever growing list of experiments suggests that understanding such phases of matter forms a crucial step towards the development of a new and general framework of condensed matter systems. We provide an introduction to such physics in the context of quantum spin liquids that would be relevant to frustrated quantum magnets. We take two examples, the two dimensional $\mathbb{Z}_2$ quantum spin liquid in Kitaev’s Toric code model, and the three dimensional $U(1)$ quantum spin liquid in the XXZ pyrochlore system, both for spin $-1/2$ to explain some of the inherent properties of quantum spin liquids, as we know them. The aim is to contrast these properties with those of conventional phases like the magnetically ordered ones. These differences range from novel excitations such as mutual semions in the form of Ising electric and magnetic charges in Toric code to emergent photons and fractionized spin $-1/2$ excitations in XXZ pyrochlores. These two examples have been chosen to bring out the differences clearly, without going into the general structure of emergent gauge theories in quantum spin liquids. However, all the principles introduced here have very general applications. [Chapter 17: Topology and condensed matter physics, Editors Somendra Mohan Bhattacharjee Mahan Mj, Abhijit Bandyopadhyay, Texts and Readings in Physical Sciences 19, Springer and Hindustan Book Agency, 2018]

Effects of ‘activity’ (self-propulsion) on the dynamics of model glass-forming liquids near the structural glass transition

We have done a numerical study of the effects of ‘activity’ (self-propulsion) on the dynamics of model glass-forming liquids near the structural glass transition. This work shows that the temperature at which a non-equilibrium glass transition in an active system occurs, decreases as the strength of the activity is increased and the transition disappears if the strength of the activity exceeds a critical value. The dependence of the glass transition temperature on the strength of activity can be understood in terms of an ‘effective temperature’ that approximately describes the effect of the presence of self-propulsion. Activity also changes the nature of the collective dynamics near the glass transition. The fragility of the liquid, which describes the degree of deviation of the temperature dependence of the structural relaxation time from the simple Arrhenius form, is found to decrease with increasing activity. Also, activity leads to swirling motion with the formation of vortices whose scale increases as the non-equilibrium glass transition is approached. The route to the glass transition in athermal active systems with large persistence time of the self-propulsion force is found to be very different from that in thermal systems. The dynamics of the liquid is found to be ‘intermittent’ in this regime, with long quiescent periods during which the particles show very little movement, separated by short ‘bursts’ that represent large displacements of a small number of particles in spatially localized regions. The formulation of a theoretical description that provides explanations of some of the interesting effects observed in simulations is in progress. [Chandan Dasgupta, Madan Rao, Pranab Jyoti Bhuyan, Rituparno Mandal, Pinaki Chaudhuri]

Numerical study of heat conduction in liquids near the glass transition

We have been working on another problem that involves a numerical study of heat conduction in liquids near the glass transition and in the aging regime obtained by quenching a liquid from a high temperature to temperatures close to or below the glass transition temperature. Several interesting results about the dependence of the thermal conductivity on the
temperature and the cooling rate, and on the waiting time in the aging regime have been obtained from simulations. It is found that the thermal conductivity of the disordered solid obtained at low temperatures depends on the cooling rate with which it was prepared, with lower cooling rates leading to lower thermal conductivity. The thermal conductivity is also found to decrease with increasing age. This decrease of the thermal conductivity is a consequence of increased exploration of lower-energy local minima of the underlying potential energy landscape. The thermal conductivity for minima with lower energy is lower because most of the harmonic modes associated with minima with lower energy are more localized. This work provides a theoretical understanding of the behaviour of the thermal conductivity of glasses in terms of the properties of the potential energy landscape of the system. [Chandan Dasgupta, Abhishek Dhar, Pranab Jyoti Bhuyan, Rituparno Mandal, Pinaki Chaudhuri]

**Exact extremal statistics in the classical 1d Coulomb gas**

For a one-dimensional classical Coulomb gas of N-like charges in a harmonic potential—also known as the one-dimensional one-component plasma, we compute, analytically, the probability distribution of the position x max of the rightmost charge in the limit of large N. We show that the typical fluctuations of x max around its mean are described by a nontrivial scaling function, with asymmetric tails. This distribution is shown to be different from the Tracy-Widom distribution for Dyson's log gas. We also compute the large deviation functions of x max explicitly and show that the system exhibits a third-order phase transition, as in the log gas. [Abhishek Dhar, A. Kundu, S. N. Majumdar, S. Sabhapandit, and G. Schehr]

**Return to origin problem for particle on a one-dimensional lattice with quasi-Zeno dynamics**

In recent earlier work, we have studied the so-called quasi-Zeno dynamics of a system in the context of the quantum first passage problem. This dynamics considers the time evolution of a system subjected to a sequence of selective projective measurements made at small but finite intervals of time. This means that one has a sequence of steps, with each step consisting of a unitary transformation followed by a projection. The dynamics is non-unitary and it can be effectively described by two different non-Hermitian Hamiltonians. We explore this connection by considering the problem of detecting a free quantum particle moving on a one-dimensional lattice, where the detector is placed at the origin and the particle is initially located at some specified lattice point. We find that results for distribution times for the first detection probability, obtained from the non-Hermitian Hamiltonians, are in agreement with known exact results as well as exact numerics. Interesting finite-size effects are discussed. [Abhishek Dhar, S. Lahiri]

**Light-cone spreading of perturbations and the butterfly effect in a classical spin chain**

The spreading of localised perturbation in a chaotic classical many-body system, the classical Heisenberg chain at infinite temperature was studied. It was found that the spread is ballistic with a finite speed, even when the local spin dynamics is diffusive. We study two complementary aspects of this butterfly effect—the rapid growth of the perturbation and its simultaneous ballistic (light-cone) spread, as characterised by the Lyapunov exponents and the butterfly speed respectively. Our study helps in the understanding of recent studies of the out-of-time-ordered commutators (OTOC), which have been proposed as an indicator of chaos in a quantum system. By analysing the scaling forms, we relate the growth, spread and propagation of the perturbation with the growth of one-dimensional interfaces described by the Kardar-Parisi-Zhang (KPZ) equation. [Abhishek Dhar, A. Das, S. Chakrabarty, D. Huse (Princeton), A. Kundu, S. S Ray, R. Moessner (MPI, Dresden), S. Bhattacharjee]

**Anomalous heat equation in a system connected to thermal reservoirs**

Anomalous transport in a one-dimensional system with two conserved quantities, in the presence of thermal baths, was studied. Exact expressions were obtained for the temperature profile and the two point correlations in the steady state as well as in the non-stationary state. In contrast to the Fourier heat equation in the diffusive case, it is shown that the evolution of the temperature profile is governed by a non-local anomalous heat equation. [Abhishek Dhar, Priyanka, Aritra Kundu, Anupam Kundu]

**Steady state, relaxation and first-passage properties of a run-and-tumble particle in one-dimension**

A one dimensional model for the motion of active
particle systems such as bacteria, was studied in one dimension. We find the exact probability distribution of the particle with and without diffusion on the infinite line, as well as in a finite interval. In the infinite domain, this probability distribution approaches a Gaussian form in the long-time limit, as in the case of a regular Brownian particle. At intermediate times, this distribution exhibits unexpected multi-modal forms. In a finite domain, the probability distribution reaches a steady-state form with peaks at the boundaries, in contrast to a Brownian particle. We also study the relaxation to the steady-state analytically and first passage properties. [Abhishek Dhar, K. Malakar, V. Jemseena, A. Kundu, K. V. Kumar, S. Sabhapandit, S. N. Majumdar (LPTMS, Orsay), S. Redner (Santa Fe, US)]

Cooling by heating in nonequilibrium nanosystems

In this work, we showed the possibility to cool nano-electronic systems in non-equilibrium situations by increasing the temperature of the environment. We demonstrated that such cooling by heating is possible for a variety of experimental conditions where the relevant transport-induced excitation processes become quenched and de-excitation processes are enhanced upon an increase of temperature. These findings have implications for open quantum systems in general, where electron transport is coupled to mechanical (phononic) or photonic degrees of freedom. In particular, molecular junctions with rigid tunneling pathways or quantum dot circuit QED systems. [R. Härtle, Manas Kulkarni, C. Schinabeck, D. Gelbwaser-Klimovsky, M. Thoss, U. Peskin]

Permanent spin currents in cavity-qubit systems

This work was connected with a recent experiment [P. Roushan et al., Nat. Phys. 13, 146 (2017)], where a spin current in an architecture of three superconducting qubits was produced during a few microseconds by creating synthetic magnetic fields. The lifetime of the current was set by the typical dissipative mechanisms that occur in those systems. We proposed a scheme for the generation of permanent currents, even in the presence of such imperfections, and scalable to larger system sizes. It relies on striking a subtle balance between multiple non-equilibrium drives and the dissipation mechanisms, in order to engineer and stimulate chiral excited states which can carry current. [S. M. Hein, E. Kapit, Manas Kulkarni, C. Aron]

Nonequilibrium phase diagram of a one-dimensional quasiperiodic system with a single-particle mobility edge

We investigated and mapped out the non-equilibrium phase diagram of a generalization of the Aubry-André-Harper (AAH) model. This generalized AAH (GAAH) model is known to have a single-particle mobility edge which also has an additional self-dual property akin to that of the critical point of the AAH model. By calculating the population imbalance, we found hints of a rich phase diagram. By placing this model far from equilibrium with the aid of two baths, we studied the open system transport via system size scaling of nonequilibrium steady state (NESS) current, calculated by fully exact nonequilibrium Green's function (NEGF) formalism. The critical point of the AAH model got generalized to a ‘critical’ line separating regions of ballistic and localized transport. Like the critical point of the AAH model, current scales sub-diffusively with system size on the ‘critical’ line. However, the scaling exponent on this line is distinctly different from that obtained for the critical AAH model. [A. Purkayastha, Manas Kulkarni, A. Dhar]

Emergence of the Calogero family of models in external potentials: duality, solitons and hydrodynamics

We presented a first-order formulation of the Calogero model in external potentials in terms of a generating function, which simplifies the derivation of its dual form. Solitons naturally appear in this formulation as particles of negative mass. Using this method, we obtained the dual form of Calogero particles in external quartic, trigonometric and hyperbolic potentials, which were known to be integrable but had no known dual formulation. We derived the corresponding soliton solutions, generalizing earlier results for the harmonic Calogero system, and presented numerical results that demonstrate the integrable nature of the soliton motion. We also gave the collective fluid mechanical formulation of these models and derived the corresponding fluid soliton solutions in terms of meromorphic fields, commenting on issues of stability and integrability. [Manas Kulkarni, A. Polychornakos]

Anomalous transport in the Aubry-Andre-Harper model in isolated and open systems

We studied the high temperature transport behavior of the Aubry-Andre-Harper (AAH) model, both in the
isolated thermodynamic limit and in the open system. At the critical point of the AAH model, we found hints of super-diffusive behavior from the scaling of spread of an initially localized wave-packet. On the other hand, when connected to two baths with different chemical potentials at the two ends, we found that the critical point showed clear sub-diffusive scaling of current with system size. We provided an explanation of this by showing that the current scaling with system-size is entirely governed by the behavior of the single particle eigen functions at the boundary sites where baths were attached. We also looked at the particle density profile in non-equilibrium steady state of the open system when the two baths are at different chemical potentials. We found that the particle density profile has distinctly different behavior in the delocalized, critical and localized phases of the AAH model. [A. Purkayastha, S. Sanyal, A. Dhar, Manas Kulkarni]

**Steady state, relaxation and first-passage properties of a run-and-tumble particle in one-dimension**

As Brownian motion describes various passive stochastic processes at the basic level, run and tumble particles have recently been proposed to describe various active stochastic processes. In this work, we have investigated various statistical properties like occupation probability, relaxation to steady state, survival probability and exit probability analytically in one dimension. We verify our results through extensive numerical simulations. [K. Malakar, V. Jemseena, Anupam Kundu, K. Vijay Kumar, S. Sabhapandit, S. N. Majumdar, S. Redner, A. Dhar]

**Unusual equilibration of a particle in a potential with a thermal wall**

Microscopic derivation of the effective erratic dynamics (Brownian) of a molecule in a solution at temperature $T$ is an important problem and is still has not been achieved in a satisfiable form. We have looked at this problem in the context of a single particle gas confined by a heavy but movable piston. In this problem, we found that the relaxation of the particle in case of a fixed piston, is logarithmic in contrast to the usual exponential relaxation. [D. Bhat, S. Sabhapandit, Anupam Kundu, Abhishek Dhar]

**Exact extremal statistics in the classical 1d Coulomb gas**

In the last decade, similar to the Gaussian distribution law, a new universal law called the Tracy-Widom distribution has emerged, which describes the typical fluctuations of the extremum of the eigenvalues of random matrices in Gaussian ensemble. This distribution has appeared in various seemingly unrelated interacting many-particle systems - indicating some kind of universality of this distribution. However, in a recent work, me and my collaborators have shown a counter-example in a specific interacting (1D Coulomb) system where the fluctuations of the maxima are not describable by the Tracy-Widom. [A. Dhar, Anupam Kundu, S. N. Majumdar, S. Sabhapandit, G. Schehr]

**Einstein relation and hydrodynamics of non-equilibrium mass transport processes**

In this work, we have derived the hydrodynamics of paradigmatic conserved mass transport processes on a ring. Remarkably, we find that the two transport coefficients, bulk diffusion coefficient and conductivity, obey an equilibrium-like Einstein relation even when the microscopic dynamics violates detailed balance and systems are far from equilibrium. We also study the probability of large deviations in density profiles. [A. Das, Anupam Kundu, P. Pradhan]

**Tagged particle in single-file diffusion with arbitrary initial conditions**

The problem of describing the motion of a tagged particle in the presence of other impenetrable particles is ubiquitous and of fundamental interest. This problem becomes harder as different particles get correlated and the effect of this correlation is strongest in one dimension. It has been understood that the mean-squared displacement of a tagged particle in such an environment is subdiffusive. We have shown that the sub-diffusive exponent depends strongly on the initial arrangement of the particles in an infinite system. [J. Cividini, Anupam Kundu]

**Interdisciplinary Mathematics**

Research focussed on topics of polymer models in KPZ universality class, stationary Gaussian processes on the line and models of self-organized criticality in non-equilibrium statistical mechanics. One notable work was where the existence of a large deviation rate function was proved for the upper tail first passage percolation, answering a question left open from the eighties. [Riddhipratim Basu, Sirshendu Ganguly and...
Allan Sly]

**Geometric Quantization of moduli space of gravitating vortices on a Riemann surface**

We are studying techniques of constructing a Quillen line bundle on the moduli space of gravitating vortices on a Riemann surface. This moduli space was studied by Alvarez-Consul, Garcia-Farrandez, Garcia-Prada and Pingali. The geometric quantization is being studied using Quillen bundle construction of Takhtajan and Zograf on the Teichmuller space and the Quillen bundle on the vortex moduli space. Discussions on with the above authors. [Rukmini Dey]

**Existence of minimal surfaces and surfaces of prescribed mean curvature interpolating between given curves**

Using mean curvature flow techniques, we are studying the problem of existence of minimal surfaces interpolating between given curves. [Rukmini Dey Mathew George and Kohinoor Ghosh]

**Characterizing time-like minimal surfaces in 3-d Lorentz-Minkowski space which have conical singularities**

Kobayashi has characterized maximal surfaces in 3-d Lorentz-Minkowski space which have conical singularities. We are studying the problem of characterizing time-like minimal surfaces in 3-d Lorentz-Minkowski space which have conical singularities. [Rukmini Dey, Aryaman Patel]

**Thin threads on the catenoid**

Rama Govindarajan and Ganga Prasath had conducted an experiment of a thin thread settling on a soap bubble (sphere) and studied its configuration. We study the same mathematical problem for the configuration of a thread on a catenoidal minimal surface. We neglect the gravity effect and just study the configuration of the thread which minimizes the bending energy. We get PDEs which characterize extrema of bending energy of the thread. [Rukmini Dey, Rama Govindarajan, Mathew George and Ganga Prasath]

**String Theory and Quantum Gravity**

**Thermality of eigenstates in conformal field theories**

The eigenstate thermalization hypothesis (ETH) provides a way to understand how an isolated quantum mechanical system can be approximated by a thermal density matrix. We find a class of operators in (1+1)-
dimensional conformal field theories, consisting of quasiprimaries of the identity module, which satisfy the hypothesis only at the leading order in large central charge. In the context of subsystem ETH, this plays a role in the deviation of the reduced density matrices, corresponding to a finite energy density eigenstate from its hypothesized thermal approximation. The universal deviation in terms of the square of the trace-square distance goes as the eighth power of the subsystem fraction and is suppressed by powers of inverse central charge \( c \). Furthermore, the nonuniversal deviations from subsystem ETH are found to be proportional to the heavy-light-heavy structure constants which are typically exponentially suppressed in \( h/c \), where \( h \) is the conformal scaling dimension of the finite energy density state. We also examine the effects of the leading finite-size corrections. [Pallab Basu, Diptarka Das, Shouvik Datta, and Sridip Pal]

**Phase Transitions of a (Super) Quantum Mechanical Matrix Model with a Chemical Potential**

In this work, we studied the finite-temperature matrix quantum mechanics with chemical potential term linear in the single trace of U(N) matrices, via Monte Carlo simulation. In the bosonic case, we found the existence of the Gross-Witten-Wadia (GWW) type third-order phase transition. We also extended our studies to the model with the fermionic degrees of freedom employing the non-lattice simulation via Fourier expansion, and explored the possibilities that there is a phase transition between the gapped and ungapped phase both in the absence and presence of the chemical potential term. [Takehiro Azuma, Pallab Basu, Prasant Samantray]

**Complex Langevin Dynamics in Large N Unitary Matrix Models**

Using complex Langevin dynamics we examined the phase structure of complex unitary matrix models and compare the numerical results with analytic results found at large N. The actions we consider are manifestly complex, and thus the dominant contribution to the path integral comes from the space of complexified gauge field configuration. For this reason, the eigenvalues of unitary matrix lie off the unit circle and venture out in the complex plane. One example of a complex unitary matrix model, with Polyakov line as the unitary matrix, is an effective description of a QCD at finite density and temperature defined on a lower dimensional manifold. A distinct feature of this model, the occurrence of a series of Gross-Witten-Wadia transitions, as a function of the quark chemical potential, was reproduced using complex Langevin simulations. We simulated several other observables including Polyakov lines and quark number density, for large N and Nf and found excellent match with the analytic results. [Pallab Basu, Kasi Jaswin, Anosh Joseph]

**Novel Tensionless Limits of String Theory**

We have been working further on the theme in my research of uncovering the unbroken symmetries of string theory in special vacua. One of the highlights in the last year was uncovering a novel tensionless limit for 3-dimensional AdS backgrounds in the presence of NS-NS flux [M. Gaberdiel, Rajesh Gopakumar and C. Hull]. With Gaberdiel we studied this limit in further detail and found a rather surprising relation between the spectra at this special point and that of the apparently different point which is described by a conventional symmetric product orbifold. We believe this is a signature and consequence of the universality of the unbroken higher spin square symmetry.

**Conformal Bootstrap in Mellin space**

This work is in the direction of understanding conformal field theories using a new approach that combines techniques from string theory, specifically gauge-string duality (‘Witten Diagrams’) and the mellin representation. This has already yielded new results for systems relevant for studying real world phase transitions. We are pushing ahead with this and trying to understand better the ambiguities due to contact Witten diagrams. [Rajesh Gopakumar, Aninda Sinha]

**Fluid dynamics from Schwinger-Keldysh/ Entropy inflow**

We have been working on formulating hydrodynamics as an effective field theory controlled by symmetries. This is in continuation of my earlier work with Felix M. Haehl and Mukund Rangamani where we had proposed a formalism to deal with effective field theory of fluid modes. Our proposal posits an emergent gauge symmetry (associated with entropy) and a supersymmetry underlying fluid dynamical path integrals. In recent work, we have succeeded in showing that this formalism does reproduce in detail many aspects of hydrodynamics completely within a Wilsonian framework governed by symmetries and effective
actions. The super-space description of fluid dynamics has many interesting features: crucially, the interpretation of entropy production as a kind of anomaly inflow from the super-space directions. [Felix M. Hael, R. Loganayagam, Mukund Rangamani]

Renormalisation in open Quantum field theories

A second set of questions involve open quantum field theories especially with regards to the structure of renormalisation. While the notion of open quantum systems (i.e., quantum systems in contact with an environment) is itself old, many of the existing studies deal with quantum mechanical systems rather than quantum field theories. One of the most widely used models of open quantum systems is the quantum master equation approach by Gorini-Kossakowski-Sudarshan and Lindblad. We tackled the issue of the emergence of such a Lindblad equation in open quantum field theories and its renormalisation. [Avinash Baidya, Chandan Jana, R. Loganayagam, Arnab Rudra]

Out of time-ordered correlators in and out of equilibrium

A third set of questions revolve around out of time ordered correlators (OTOCs) in a variety of systems, especially at finite temperature. We studied the general structure of path integrals which compute OTOCs and the generalized fluctuation dissipation theorems for OTOCs. We described general features of thermal correlation functions in quantum systems, with specific focus on the fluctuation-dissipation type relations implied by the KMS condition. We used these observations to then construct a natural causal basis for thermal N-point functions at generic frequencies in terms of fully nested commutators. [Felix M. Haehl, R. Loganayagam, Prithvi Narayan, Amin Ahmad Nizami, Mukund Rangamani]

Loss of locality in quantum gravity

In previous work on the information paradox, we had found indications that, in some regimes, the principle of locality breaks down in quantum gravity. In work with my student at ICTS, Sudip Ghosh, we had found additional evidence for this interesting phenomenon by consider string perturbation theory in a limit where the number of particles becomes large but the energy per particle stays finite. We continued this analysis by examining superstring perturbation theory. We found that, even for superstrings, perturbation theory was invalidated in the regime above. In theories of gravity, the breakdown of perturbation theory is often a sign of the breakdown of naive notions of locality, and therefore our results provide additional evidence the idea that locality breaks down if we probe spacetime at “too many points.” [Suvrat Raju, Sudip Ghosh]

Quantum Information Measures for Restricted Sets of Observables

If locality breaks down in quantum gravity, this raises the following interesting question: how do we define local measures of quantum information if we cannot precisely localize degrees of freedom. In work with Sudip Ghosh, we generalized standard measures of quantum information to cover this scenario. The mathematical problem that we addressed was the following: given a set of observables that may not be closed under multiplication, can one define a good notion of quantum entanglement. This is relevant for gravity because the loss of locality indicated above occurs precisely because the product of a large number of local observables may not itself be a good local observable. We believe that our results may also have applications in quantum information theory since they provide a method of defining “coarse-grained” quantum information measures. [Suvrat Raju, Sudip Ghosh]

Sachdev-Ye-Kitaev (SYK) model and emergence of quantum gravity in 2-dims

Besides being a large N soluble model that provides a diagnostic of a black hole state, the SYK model also affords an opportunity to see if a dual quantum spacetime emerges from the ingredients of the lower dimensional theory on its boundary. At large N and strong coupling the model has an emergent 1-dim reparametrization symmetry in the infrared. We recognised that quantizing the co-adjoint orbit of this symmetry group naturally leads to a theory in one higher space-time dimension, which is Polyakov’s 2-dim quantum gravity (in a specific gauge). Once the arena of gravitational dynamics in 2-dims emerges it is natural to add a volume term with a cosmological constant to the Polyakov action. A negative value of the cosmological constant ensures that the (Euclidean) space-time is non-compact and has a boundary. In particular AdS2 space-time is a solution. It turns out that this model has no local degrees of freedom due to local diffeomorphism constraints and the dynamics is entirely described by the Schwarzian action of the
residual large diffeomorphisms on the boundary of the 2-dim space-time. The quantum chaos exponent computed in this 2-dim gravity model agrees with the SYK model. [G. Mandal, P. Nayak, and S. R. Wadia]

Members


Visiting Fellows


Graduate Students


Associated Faculty

Rana Adhikari (Caltech, USA), Shivani Agarwal (University of Pennsylvania, USA), K. G. Arun (Chennai Mathematical Institute), Gyan Bhanot (Rutgers University, USA), Sayantani Bhattacharyya (NISER Bhubaneswar), Debasis Chaudhuri (Institute of Physics, Bhubaneswar), Kedar Damle (TIFR, Mumbai), Subinoy Das (Indian Institute of Astrophysics, Bangalore), Justin David (Indian Institute of Science, Bangalore), Nivedita Deo (University of Delhi), Abhijit Gadde (TIFR, Mumbai), Sidhartha Goyal (University of Toronto, Canada), Karthik Gurumoorthy (Amazon Development Centre, Bangalore), Shravan Hanasoge (TIFR, Mumbai), Mark Hannam (Cardiff University, UK), Sascha Hua (University of the Balearic Islands, Spain), Zubin Jacob (Purdue University, USA), Kavita Jain (JNCASR, Bangalore), Sanjay Jain (University of Delhi), Dileep Jatkar (HRI, Allahabad), Sandeep Krishna (NCBS, Bangalore), Badri Krishnan (Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and Institute for Gravitational Physics of the Leibniz Universität Hannover), Swapna Mahapatra (Utkal University, Bhubaneswar), Gautam Mandal (TIFR, Mumbai), Narayanan Menon (University of Massachusetts Amherst), Tapan Mishra (IIT Guwahati), Onuttom Narayan (University of California, Santa Cruz, USA), Biman Nath (Raman Research Institute, Bangalore), Arun Paramekanti (University of Toronto, Canada), Shiroman Prakash (Dayalbagh Educational Institute, Agra), Surjeet Rajendra (University of California, Berkeley, USA), Sumathi Rao (HRI, Allahabad), Madan Rao (Simons Center for the Study of Living Machine, NCBS-TIFR), Sanjib Sabhapandit (Raman Research Institute, Bangalore), Tridib Sadhu (TIFR, Mumbai), B. S. Sathyaprakas (Pennsylvania State University and Cardiff University), Diptiman Sen (Institute of Science, Bangalore), Anand Sengupta (IIT Gandhinagar), Anirvan Sengupta (Rutgers University, USA), Prajval Shastri (Indian Institute of Astrophysics, Bangalore), Ravi Sheth (ICTP and The University of Pennsylvania), Aninda Sinha (Indian Institute of Science, Bangalore), Piyush Srivastava (TIFR, Mumbai), Nisheeth Vishnoi (École polytechnique fédérale de Lausanne EPFL, Switzerland)
Support Staff

National and International Involvement

P. Ajith
1. Member, Editorial board, Journal of Astrophysics and Astronomy (Indian Academy of Sciences)
2. Member, GWIC Thesis Prize and Stefano Braccini Thesis Prize selection committee

Amit Apte
1. Editor, Nonlinear Processes in Geosciences
2. Co-organiser, Dynamics of Complex Systems 2017, ICTS-TIFR, Bangalore, 10 May-25 June, 2017

Subro Bhattacharjee
Co-organiser, Asia-Pacific workshop on frustrated magnetism, Seoul, August 2017

Chandan Dasgupta

Rukmini Dey
Co-organiser, J-Holomorphic Curves and Gromov-Witten Invariants, ICTS-TIFR, Bangalore, December-January, 2018

Abhishek Dhar
1. Editorial board member, Pramana journal of physics
2. Co-organiser, Bangalore school on statistical physics, ICTS-TIFR, Bangalore, June-July 2017
3. Co-organiser, Workshop on open quantum systems, ICTS-TIFR, Bangalore, July-August 2017
4. Co-organiser, Discussion meeting on stochastic thermodynamics and active systems, ICTS-TIFR, Bangalore, August 2017
5. Co-organiser, Workshop on large deviation theory, ICTS-TIFR, Bangalore, August-October 2017
6. Co-organiser, Indian statistical physics community meeting, ICTS-TIFR, Bangalore, February 2018

Rajesh Gopakumar
1. Member, Editorial Board, Physical Review Letters
2. Member, Board of the NBHM (DAE)
3. Member, Sectional Committee (Physics), IAS
4. Member, International Advisory Committee, Strings 2017, Tel-Aviv
5. Member, International Advisory Committee, Strings 2018, Okinawa, Japan
6. Member, IUPAP C18 commission on Mathematical physics (till Dec. 2017)
7. Secretary, IUPAP C18 commission on Mathematical physics (Jan. 18 onwards)
8. Co-organiser, ICTS at Ten, ICTS-TIFR, Bangalore, 5-7 January 2018

Rama Govindarajan
1. Fluid Dynamics Prize Committee Member, American Physical Society, 2018
4. Chairman, Mechanical and Civil Engineering PAC (Programme Action Committee), Science and Engineering Research Board (SERB), Department of Science and Technology (DST) Government of India, 2016-present.
5. Member, Sectional Committee, Engineering Sciences, Indian Academy of Sciences, 2016-present.
6. Executive Committee Member, Samaj Pragati Sahyog, Indian Academy of Sciences, 2016
7. Editorial Board member, Pramana.
8. Fellow, Indian Academy of Sciences, National Academy of Sciences India and the American Physical Society
9. Co-organiser, Turbulence from Angstroms to Light Years, ICTS-TIFR, Bangalore, January 2018

Bala Iyer
1. Member, Program Committee of LIGO Scientific Collaboration
2. Member, International Society on General Relativity and Gravitation (ISGGR)
3. Member, American Physical Society (APS) USA
4. Member, International Astronomical Union (IAU)
5. Member, Indian Association for General Relativity and Gravitation (IAGRG)
6. Member, Indian Physics Association Bangalore Chapter
7. Committee Member, International Society of Organization General Relativity and Gravitation, 2010-2019
8. PI, IndIGO-LSC in LIGO Scientific Collaboration (LSC), 2014 - present
9. Member, Governing Council, BASE, Jawaharlal Nehru Planetarium, Bangalore, 2013
11. IndIGO Representative on Gravitational Wave International Committee (GWIC), 2011- present
12. IndIGO-LSC member in LIGO Scientific Collaboration (LSC), 2011 - present
13. Chair, IndIGO Consortium, 2009 - present
14. Editor in Chief and Subject Editor on Gravitational Waves, Living Reviews in Relativity (Online Journal), Springer, Heidelberg, Germany, 2016 - present
15. Member, Editorial Board of Classical Quantum Gravity IOP, UK, 2016 - present
16. Member, SOC: XII Amaldi meeting, Pasadena, 2017
17. Member, SOC: 22nd International Conference on General Relativity and Gravitation, (GR22), Valencia, Spain, 2019
18. Member, International Coordinating committee, 15th Marcel Grossman meeting (MG14), Rome, 2018
22. Co-organiser of Cosmic fireworks: The dawn of multimessenger astronomy, 19 October 2017

Vijay Kumar Krishnamurthy
1. Co-organiser of ICTS-ICTP Winter school on quantitative systems biology, ICTS-TIFR, December 2017
2. Co-organiser, Stochastic Thermodynamics Active Matter and Driven Systems, ICTS-TIFR, August 2017

Manas Kulkarni
Co-organiser, Open Quantum Systems, ICTS-TIFR, Bangalore, 17 July-4August, 2017

R. Loganayagam
1. Co-organiser, Nonperturbative and Numerical Approaches to Quantum Gravity, String Theory and Holography, ICTS-TIFR Bangalore, Jan-Feb 2018
2. Co-organiser, Kavli Asian Winter School (KAWS) on Strings, Particles and Cosmology, ICTS-TIFR, Bangalore, January 2018
3. Co-organiser, Bangalore Area String Meeting, ICTS-TIFR, Bangalore, July-August 2017

Sourat Raju
1. Co-organiser, Kavli Asian Winter School (KAWS) on Strings, Particles and Cosmology 2018, ICTS-TIFR, Bangalore, 8-18 January, 2018
2. Co-organiser, Bangalore Area String Meeting, ICTS-TIFR, Bangalore, July-August 2017

Shashi Thutupalli
1. Thesis Committees of: Sachit Daniels, NCBS (Advisor: Mukund Thattai); Jitesh Jhawar, IISc (Advisor: Vishwesha Guttal, IISc); Vinay Sagar, NCBS (Advisor: Uma Ramakrishnan)
2. Referee, Central European Journal of Physics, Chaos, eLife, Microfluidics and NanoFluidics
4. Grant Proposal Reviewing of Complex Systems Institute Paris Ile-de-France (ISC-PF), CEFIPRA
6. Organiser, Max Planck Partner Group Symposium, NCBS Bangalore, 14 April 2017

Vishal Vasan
Co-Organiser, ICTS Summer School and Discussion Meeting on Bouyancy Driven Fluid Flows, ICTS-TIFR Bangalore, 12-20 June 2017

Spenta R. Wadia
1. Member, International Advisory Committee (IAC) of the International Institute of Physics (IIP) in Natal, Brazil, 2017
2. Member, Jury Panel, Infosys Science Foundation Prize for Physical Sciences, 2015 - present
3. Member, Sectional Committee for Physics, Indian National Science Academy, New Delhi, 2017- present
5. Member, Science Council of Asia Pacific Centre for Theoretical Physics (APCTP), S. Korea, 2010- present
6. Member Advisory Board, Asia Pacific Mathematics Newsletter, World Scientific, 2010- present
7. Program Advisory Committee, IAS Nanyang Technological University, Singapore, 2009- present
8. Steering Committee, Kavli Asian Winter School on Strings, Particles and Cosmology, which is held in China, Japan, Korea and India every year by rotation
9. Physics Sectional Committee, Indian National Science Academy, Delhi, India
Visits

Amit Apte
Statistical and Applied Mathematical Sciences Institute (SAMSI), Durham NC, USA as Visiting Fellow, August 2017-June 2018

Pallab Basu
1. TIFR, Mumbai, February 2018
2. BITS-Pilani, Hyderabad, February 2018
3. IIT Kharagpur, April 2018

Riddhipratim Basu
Indian Statistical Institute, Kolkata, December 2017

Subhro Bhattacharjee
1. IMSc, Chennai, April 2017
2. IACS, Kolkata, June 2017
3. IIT Kanpur, July 2017
4. TIFR Mumbai, August 2017
5. Max Planck Partner Group, Dresden, Germany, September-October 2017
6. NEHU Shillong, November 2017
7. TIFR-Hyderabad, January, 2018
8. IACS Kolkata, February, 2018
9. IIT Madras, Chennai, March 2018
10. Max Planck Institute for the Physics of Complex Systems (MPIPKS), Dresden, Germany, March 2018
11. ISI and Presidency University, Kolkata, February 2018
12. S. N. Bose Centre, Kolkata, February 2018
13. ICTP-SAIFR, Sao Paulo, Brazil, May-June 2017
14. Institute for Theoretical Physics, ETH Zurich, Switzerland, July 2017
15. Institut d’Etudes Scientifiques de Cargèse (IESC Cargèse), Corsica, France, July 2017
16. National Center of Theoretical Science (NCTS) at National Tsing-Hua University, Taiwan, August 2017
17. IISER, Pune, August 2017
18. Far Eastern Federal University (FEFU), Vladivostok, Russia, October, 2017
19. Princeton Center for Theoretical Science, Princeton University, New Jersey October-November 2017
20. Saha Institute of Nuclear Physics, Kolkata, February, 2018
21. IACS, Kolkata, February 2018
22. IIT Madras, Chennai, March 2018
23. Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, March 2018
24. Universidad Andres Bello, Pucón, Chile April, 2018

Rama Gonsindarajan
1. University of California, Santa Barbara, September 2017
2. Max Planck Institute of Dynamics and Self Organisation, August 2017

Vijay Kumar Krishnamurthy
1. IISER Mohali, March 2017
2. MPIPKS Dresden, October-November 2017
3. DBT Ramalingaswami conclave, NIPGR, New Delhi, January 2018
4. IIT Gandhinagar, March 2018
5. TCIS-Hyderabad, April 2018

Manas Kulkarni
1. IMSc, Chennai, January 2018
2. Princeton University, USA, November-December 2017
3. University of Toronto, October-November 2017
4. Soochow University, Suzhou, China, December 2017
5. TIFR Centre for Interdisciplinary Sciences, Hyderabad, June 23, 2017
6. TIFR Mumbai, May 2017

Anupam Kundu
LPTMS, Orsay, University Paris Sud, December 2017

R. Laganayagam
1. SINP, Kolkata, February 2018
2. IISER Pune, October 2017
3. TIFR, Mumbai, October 2017
4. Tel Aviv, Israel, June 2017

Suvrat Raju
Strings 2017, Tel Aviv, IIT Guwahati

Samriddhi Sankar Ray
University of Nice, France, as CNRS visiting professor, September 2017

Shashi Thutupalli
1. KITP, Santa Barbara, USA, February 2018
2. Max Planck Institute for Cell Biology and Genetics, Dresden, Germany, January 2018
3. Max Planck Institute for Physics of Complex Systems, Dresden, Germany, January, 2018
4. Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany, January 2018

Invited Talks

P. Ajith
1. Einstein’s messengers. 36th Annual Meeting of the Astronomical Society of India, Hyderabad, Feb 2018
2. Physics and astronomy from gravitational-wave observations. ICTS@10, Bangalore, January 2018
3. Gravitational waves: The new frontier of Astrophysics. 29th Texas Symposium on Relativistic Astrophysics, Cape Town, South Africa, December 2017
4. LIGO: The new frontier of astrophysics. National Symposium on NSM Grid over NKN, Bangalore, October 2017

Subhro Bhattacharjee
1. Light-cone spreading of perturbations and the butterfly effect in a classical spin systems. International Workshop on Chaos and Dynamics in Correlated Quantum Matter, Dresden, Germany, January, 2018
2. Quantum spin Liquids Overview of perturbations and the butterfly effect in a classical spin chain. Conference on Driven quantum systems, IACS, Kolkata, February, 2018
3. Light-cone spreading of perturbations and the butterfly effect in a classical spin chain. Conference on Driven quantum systems, IACS, Kolkata, February, 2018
5. Quantum spin liquids in kagome antiferromagnets. School and Conference on frustrated magnetism, IMSc, Chennai

Chandan Dasgupta
1. Glass Transition in Dense Systems of Self-propelled Particles. CMPCS Conference, Pune, October 2017
4. Glass Transition in Supercooled Liquids with Medium Range Crystalline Order. Conference on Recent Advances in Molecular Simulations, IISc, Bangalore, February 2018
5. Fast and Slow Liquid Phases in a System of Self-propelled Particles. KITP, Santa Barbara, February-March 2018

Rakmini Dey
1. Geometric Quantization: Various moduli spaces and the Toda system. Conference on Analytic and Algebraic Geometry, ICTS-TIFR, March 2018
2. Some aspects of minimal surfaces and solitons. Calcutta University, January 2018
3. Some aspects of minimal surfaces and solitons. ICMAT, Madrid, Spain, Nov 2017
4. Some aspects of minimal surfaces and solitons. Symposium for South Asian Women in Mathematics,
Tribhuvan University, Kathmandu, Nepal, Oct 2017

5. Geometric Quantization, Lectures at Workshop on J-holomorphic curves and Gromov-Witten invariants. NISER, Bhubaneswar, July 2017

6. Some aspects of minimal surfaces, maximal surfaces and solitons. Annual Conference on Indian Women and Mathematics, IISc, Bangalore, July 2017

7. Some aspects of minimal surfaces, maximal surfaces and solitons, 32nd Annual Conference, Ramanujan Math. Soc., RCU, Belagavi, June 2017

Abhishek Dhar


2. Sub-diffusion and non-equilibrium probes of phases in Aubry-Andre-Harper Model. Granada Seminar on Computational and Statistical Physics, Granada, Spain, June 2017

3. Sub-diffusion and non-equilibrium probes of phases in Aubry-Andre-Harper Model. Workshop on ‘Quantum Thermodynamics: Thermalization and Fluctuations’, Yukawa Institute of Theoretical Physics, Kyoto, Japan, September 2017

4. Non Hermitian description of the Quasi-Zeno dynamics of a quantum particle, 7th Indo-Israel meeting on condensed matter physics, Indian Institute of Science, Bangalore, October 2017

5. Fractional diffusion equation description of anomalous heat transport. Workshop on Correlations, Fluctuations and anomalous transport in systems far from equilibrium, Weizmann Institute, Israel, December-January 2018

6. Hydrodynamics and Chaos Propagation in Classical Spin Chain. ICTS at Ten, ICTS-TIFR, Bangalore, January 2018

7. Puzzles in the theory of heat conduction in low-dimensional systems. Conference on Statistical Physics, ISI and Presidency University, Kolkata, February 2018


Rajesh Gopakumar

1. Bootstrap approach to conformal Field theories and Application’. Symposium at Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, March 2018

2. Aryabhatta Colloquium, Dept. of Physics, IIT Madras, March 2018

3. IACS Colloquium, Indian Association for Cultivation of Science, Kolkata, February 2018

4. Lectures at Modern Aspects of String Theory Workshop, SINP, Kolkata, February 2018

5. Lectures at J-Holomorphic Curves and Gromov-Witten Invariants, ICTS-TIFR, Bangalore, December 2017

6. ICTS workshop on Twenty Years of AdS/CFT, Princeton University, USA, November 2017

7. Workshop on ‘Integrability and Chaos in Multicomponent Systems’ in FEFU, Vladivostok, Russia, October 2017

8. Twentieth Anniversary Meeting of NCTS, National Tsing-Hua University, Taiwan, August 2017

9. Bangalore Area Strings Meeting, ICTS-TIFR, Bangalore, August 2017

10. Lectures at Exact Methods in Low dimensional Physics, Cargese Summer School, IESC Cargèse), Corsica, France, July 2017

11. String theory and Quantum Gravity at Monte Verita in Ascona, Institute for Theoretical Physics, ETH Zurich, July 2017

12. Simons Workshop - Bootstrap 2017, ICTP-SAIFR, Sao Paulo, Brazil, May 2017


Rama Govindarajan

1. AICTE workshop on Introduction to Hydrodynamic Stability, IIT Madras, March 2018

2. Turbulence, from Angstroms to Light Years, ICTS International Meeting, January 2018

3. Dynamics of Gravity Currents, IUTAM/AMERIMECH Symposium, Santa Barbara, September 2017

Bala Iyer

1. The Rapid Leap from Gravitational Wave Detection to Multi-Messenger Astronomy. Distinguished BOSE-125 Lecture, S. N. Bose Centre for Basic Sciences, Kolkata, March 2018

2. The detection of gravitational waves and the two body problem in general relativity - A personal view. K L Memorial Distinguished Lecture, CMI, Chennai, January 2018

3. Panel Discussion on Ringdown, and Panel Member for Science drivers for 3G detectors: Fundamental Physics and Cosmology, PAX Nikhef, August 2017


Vijay Kumar Krishnamurthy

1. ICTS-ICTP Winter school on Quantitative Systems Biology, ICTS, Bangalore, December 2017

2. Stochastic Thermodynamics Active Matter and Driven Systems 2017, ICTS, Bangalore, August 2017

3. Workshop on Physical and Systems Biology, ICTS, Bangalore, April 2017
4. EMBO program on Experimental and Theoretical approaches to cell mechanics, Raman Research Institute, Bangalore, April 2017

Manas Kulkarni
1. Nonlinear dynamics: From integrable models to cold atomic gases. Conference on Recent Trends in Cold and Ultracold Matter, IIT Guwahati, March 2018
2. Permanent spin currents and entanglement in cavity-qubit systems. Conference on Emergent phenomenon in classical and quantum systems, S. N. Bose National Centre for Basic Sciences, Kolkata, February 2018
3. Photon gain and statistics in driven quantum dot circuit-QED systems. Conference on Driven Quantum Systems, Indian Association for the Cultivation of Science (IACS), Kolkata, February 2018
4. Nonlinear dynamics: From integrable models to cold atomic gases. Indian Institute of Technology, IIT-Kanpur, February 2018
5. Driven Incommensurate lattice models in low dimensions. The Institute of Mathematical Sciences (IMSc), Chennai, January 2018
6. Universality in driven incommensurate models, Department of Physics, New York University, USA, December 2017
7. Permanent spin currents and entanglement in cavity-qubit systems. Yale Quantum Institute, Yale University, USA, November 2017
8. Open quantum system generalization of Incommensurate lattice models in low dimensions. Conference on Progress in quantum collective phenomena – from MBL to black holes, Simons Center for Geometry and Physics, Stony Brook, USA, November 2017
9. Incommensurate lattice models in low dimensions with and without mobility edge. Department of Physics, McMaster University, Canada, November 2017
10. Non-equilibrium phase diagram of a 1D quasiperiodic system with a single-particle mobility edge. Chemical Physics Theory Group, Department of Chemistry, University of Toronto, Canada, November 2017
11. An open quantum system generalization of a 1D quasiperiodic system with a single-particle mobility edge. Center for Phonics and Thermal Energy Science, Tongji University, Shanghai, China, September 2017
12. Permanent spin currents and entanglement in cavity-qubit systems. Quantum Workshop, Suzhou, China, September 2017
13. An open quantum system generalization of a 1D quasiperiodic system with a single-particle mobility edge. Program on Open Quantum Systems, ICTS-TIFR, Bangalore, July-August 2017
15. Sub-diffusion and non-equilibrium probes of phases in incommensurate lattice models in low dimensions. TIFR Centre for Interdisciplinary Sciences, Hyderabad, June 2017
16. Recent progress in non-equilibrium physics with Light and Matter, 35th Samahang Pisika ng Pilipinas Physics Conference, Cebu City, Philippines, June 2017
17. Sub-diffusion and non-equilibrium probes of phases in incommensurate lattice models in low dimensions. TIFR, Mumbai, May 2017

Anupam Kundu
2. Anomalous temperature profiles in open systems. SRtp workshop on Correlation, Fluctuations and anomalous transport in systems far from equilibrium, Weizmann Institute of Science, December 2017-January 2018

R. Loganayagam
1. Influence functionals: Their structure and renormalization. AdS/CFT at 20 and Beyond, ICTS-TIFR, May 2018
2. On Schwinger Keldysh Formalism. In-house Discussion Meeting on OTOCs, ICTS-TIFR, April 2018
3. OTOC: Column vector representation. IV Saha Theory Workshop, Modern Aspects of String Theory, February 2018
4. Open Quantum Field Theory. Physics departmental seminar, IISER Pune, October 2017
5. Open EFT and Renormalisation (Parts 1 and 2). Quantum Spacetime Seminar, TIFR, Mumbai, Oct 2017
6. Out of Equilibrium, Out of Time Order, Strings 2017, Tel Aviv, June 2017

Suvrat Raju
1. ICTS@10, ICTS, Bangalore, 2018
2. Strings 2017, Tel Aviv
3. Indian Association of General Relativity and Gravitation, 29th meeting, IIT Guwahati, 2017
4. First Mandelstam School on Theoretical Physics, Durban, 2017
5. String Theory: Past and Present, ICTS, Bangalore, 2017
6. TEDx, BITS, Goa, 2017
7. Einstein Lecture (ICTS), Science Festival, National College, Bangalore, 2017
8. Science Festival, National College, Bangalore, 2017

Samarth Sankar Ray
Decimated Navier-Stokes Turbulence. Institute of Mathematical Sciences (IMSc) Chennai, India, May 2017

Shashi Thutupalli
1. Collective behavior and self-organization in synthetic active matter. Conference on Collective Behaviour,
ICTP, Trieste, Italy, May 2018
2. Self-organized structures of active matter via controlled phase separation. Simons Foundation Conference on Theory and Biology, New York City, USA, April 2018
4. Disordered systems far from equilibrium. French-Indian meeting on plasticity and rheology in amorphous solids, in connection with glassy dynamics, Grenoble, France, June 2017
5. Bacterial Morphogenesis: Collections and single cells. ICTS Program on the Dynamics of Complex Systems, ICTS, Bangalore, June 2017

Vishal Vasan
1. Inverse problems in water waves. Seminar at S. N. Bose National Centre for Basic Sciences, Kolkata, February 2018
2. Analysis of shear instabilities in fluid mechanics. Climate Seminar Series, Interdisciplinary Program on Climate Studies, IIT Bombay, August 2017
3. An introduction to UTM and its applications. CAM-TIFR Colloquium, Bangalore, August 2017

Programs Organized by the Centre

Dynamics of Complex Systems – 2017
ICTS-TIFR, Bangalore, 10 May-8 July 2017

Correlation and Disorder in Classical and Quantum Systems
ICTS-TIFR, Bangalore, 29 May - 2 June 2017
(Organizers: Awek Bid, Pinaki Chaudhuri, Tanmay Das, S. Karmakar, Prabal Maiti, Subroto Mukerjee, Srikanth Sastry)

Summer school and Discussion Meeting on Buoyancy-driven flows
ICTS-TIFR, Bangalore, 12 – 20 June 2017
(Organizers: Jaywant Arakeri, Anirban Guha, Pankaj Misra, Jai Sukhatme, Vishal Vasan and Mahendra Verma)

Bangalore School on Statistical Physics – VIII
ICTS-TIFR, Bangalore, 28 June -14 July 2017
(Organizers: Abhishek Dhar and Sanjib Sabhapandit)
4. The Unified Transform Method for nonlocal PDEs. Recent Advances in Nonlinear Waves, Seattle USA, July 2017
5. Analysis of an instability in stratified fluid flow. ICTS Discussion Meeting on Buoyancy driven fluid flows, Bangalore, June 2017
6. A model for wind driven water waves. ICERM Water Waves conference, Providence USA, April 2017
7. Pressure boundary conditions in viscous incompressible flows. ICERM Singularities and Waves in Incompressible Fluids, Providence RI, April 2017

Sanjib Sabhapandit
1. Black Holes and the Sachdev-Ye-Kitaev type Models. Simons Centre for Geometry and Physics, Stony Brook, March 2018
2. Great Ideas of Physics: From Newton to Einstein and Beyond. Dayanand Sagar University, Bangalore, February 2018

Summer School on Gravitational-Wave Astronomy
ICTS-TIFR, Bangalore, 17-28 July 2017
(Organizers: P. Ajith, K. G. Arun and Bala R. Iyer)

Open Quantum Systems
ICTS-TIFR, Bangalore, 17 July - 4 August 2017
(Organizers: Abhishek Dhar, Manas Kulkarni, Jason Petta, Anatoli Polkovnikov, Siddiq Rangwala, Dilipendu Roy and Rajamani Vijayaraghavan)

Large Deviation Theory in Statistical Physics: Recent Advances and Future Challenges
ICTS-TIFR, Bangalore, 14 August-13 October 2017
(Organizers: Arvind Ayyer, Frank den Hollander, Abhishek Dhar, Juan P. Garrahan, Christopher Jarzynski, Manjunath Krishnapur, Tony Leizee, Sanjib Sabhapandit and Hugo Touchette)

Geometry, Groups and Dynamics (GGD) - 2017
ICTS-TIFR, Bangalore, 6-24 November 2017
(Organizers: C. S. Aravinda, Sbririkrisna Dani, Krishnendu Gongopadhyay and Athanas Papadopoulos)
Winter School on Quantitative Systems Biology
ICTS-TIFR, Bangalore, 4-22 December 2017
(Organisers: Siddhartha Goyal, Kavita Jain, Vijaykumar Krishnamurthy, Luca Peliti and Mukund Thattai)

J-Holomorphic Curves and Gromov-Witten Invariants
ICTS-TIFR, Bangalore, 25 Dec 2017 - 4 Jan 2018
(Organisers: Somnath Basu, Raikunmi Dey and Rizwik Mukherjee)

Kavli Asian Winter School (KAWS) on Strings, Particles and Cosmology 2018
ICTS-TIFR, Bangalore, 8-18 January 2018

Discussion Meetings
Candles of Darkness
5-9 June 2017 (Organisers: Gautam Bhattacharyya, Amol Dighe, Sreeprap Raychaudhuri and Seema Sharma)

Airbus Day
28 July 2017 (Organisers: CAM-TIFR and ICTS-TIFR)

Bangalore Area Strings Meeting
31 July-2 August 2017 (Organisers: R. Loganayagam and Surrat Raju)

Stochastic Thermodynamics, Active Matter and Driven Systems
7-11 August 2017 (Organisers: Abhishek Dhar, Rajesh Ganapathy, V. Krishnamurthy and Sriram Ramaswamy)

Collective Dynamics of-, on- and around Filaments in Living Cells: Motors, Maps, Tips and Tracks
28 October-2 November 2017 (Organisers: Tanweer Hussain, Ambarish Kumar and Prabal K Maity)

Collective Dynamics of-, on- and around Filaments in Living Cells: Motors, MAPs, TIPs and Tracks
28 October-2 November 2017 (Organisers: Tanweer Hussain, Ambarish Kumar and Prabal K Maity)

Surface Group Representations and Geometric Structures
27-30 November 2017 (Organisers: Siddhartha Gadgil, K. Gongopadhyay, Subhojoy Gupta and Maban Mj)

Consultation on National Education Policy (NEP)
2017
2 December 2017 (Organisers: Manjul Bhargava, Leena Gopinath, Abhishek Dhar, Kavita Jain, Rahul Pandit, Sanjib Sabhapandit, Srabani Sengupta, Sankar Ray and Prerna Sharma)

Nonperturbative and Numerical Approaches to Quantum Gravity, String Theory and Holography
ICTS-TIFR, Bangalore, 27 January-3 February 2018
(Organisers: Poul H. Damgaard, Masanori Hanada, Anosh Joseph, Loganayagam R, Aninda Sinha and Toby Wiseman)

Third Bangalore School on Population Genetics and Evolution
ICTS-TIFR, Bangalore, 5-17 March 2018
(Organisers: Deepa Agarwal and Kavita Jain)

Chandran-Wadia and Spenta R. Wadia)

Statistical Physics Methods in Machine Learning
26-30 December 2017 (Organisers: Mikhail Belkin, Chandan Dasgupta, Partha Mitra and Rina Panigrahy)

Algorithms and Optimization
2-3 January 2018 (Organisers: Prateek Jain and Nisheeth K. Vishnoi)

ICTS at Ten
4-6 January 2018 (Organisers: Rajesh Gopakumar and Spenta R. Wadia)

Turbulence from Angstroms to Light Years
20 January 2018 - 25 January 2018 (Organisers: Rama Govindarajan and Shrawan Hananag)

Indian Statistical Physics Community Meeting 2018
16-18 February 2018 (Organisers: Ranjini Bandyopadhyay, Abhishek Dhar, Kavita Jain, Rahul Pandit, Sanjib Sabhapandit, Samriddhi Sankar Ray and Prerna Sharma)

Analytic and Algebraic Geometry

Pressing for Progress: A Discussion Meeting on the Gender Gap in Physics
22 March 2018 (Organisers: Prajval Shastri)
Non-DAE Research Projects

P. Ajith
1. PI (with B. S. Sathyaprakash, Penn State) of the IndoUS Centre for the Exploration of Extreme Gravity, 2016 - 2018 (Funded by the Indo-US Science and Technology Forum)

Riddhipratim Basu
Ramanujan Fellowship, DST, 2017-2022

Subhro Bhattacharjee
1. Co-investigator, project titled ‘Correlated condensed matter physics’, Max-Planck-ICTS partner group starting April 1, 2017 for three years (with Professor Roderich Moessner, Director, MPPKS, Dresden, Germany)
2. Project titled, ‘Quantum Spin Liquids and Non-Fermi Liquid Metals Funding Agency’ for three years starting June 2017 (Early Career Research Award by SERB-DST, Government of India)

Abhishek Dhar
1. Energy Diffusion in Noisy Hamiltonian Systems, French national research agency (ANR), 2014 – 2019 (with Cedric Bernardin, Francois Huveneer, Jami Lukkarinen, Marielle Simon)
2. Extreme events and large deviations in strongly correlated many body systems, CEFIPRA Indo-French project, 2016 - 2019 (with Gregory Schehr, Anupam Kandu, Sanjib Sabhapandit, Satya Majumdar, Alberto Rosso, Cedric Bernardin, Kirone Mallick)

Rajesh Gopakumar
‘Unravelling String Theory’, J. C. Bose Fellowship, DST, 2015 - 2020

Rama Govindarajan
Co-investigator, project titled ‘Coupled Physical Processes in the Bay of Bengal and Monsoon Air-Sea Interaction’ under the Monsoon Mission of the Ministry of Earth Sciences (This project ends in March 2019)

Bala Iyer

Vijay Kumar Krishnamurthy
1. DBT-Ramalingaswami re-entry fellowship ‘Mechanobiological patterns in morphogenesis’, 2016 -2020
2. Max Planck Partner group ‘Chirality of the actomyosin cortex, mechanochemical pattern formation, and left-right axis establishment in developing embryos’, 2016 - 2018 (+2 years extendable)

Anupam Kandu
1. Anomalous heat transport in open classical interacting many-particle systems, for three years starting June 2017 (Early Career Research Award by SERB-DST, Government of India)

Suvrat Raju
1. Collaborative Research titled, ‘Holography and its applications’, Indo-French Centre for the Promotion of Advanced Research, 2016-18 (with Sandip Trivedi, Ashoke Sen, Nick Halmagyi)
2. ‘Holographic Investigations of the Black Hole Interior’, Swarnajayanti Fellowship, Department of Science and Technology, 2018 - 2023

Samriddhi Sankar Ray
ECR/2015/000361 (Early Career Research grant from DST, India), project titled ‘Collisions, Coalescences and Fragmentation of Droplets in Turbulent Flows: The Role of Turbulence in Triggering Rain’, 2016 – 2019,

Shashi Tuthupalli
1. ‘Self-organization of cellular form and function’, Max Planck Partner Group, 3+2 years
2. Simons Foundation Targeted Grant, Simons Center for the Study of Living Machines, for 5 years (with Shachi Gosavi, Sandeep Krishna, Madan Rao, Mukund Thattai)
3. ‘Active morphological colloids for pathogen processing’, HFSP Young Investigator Grant, for 3 years (with Geert van den Bogaart, Stefano Sacanna)

Vishal Vasan
Collaborative Research titled, ‘Nonlinear Waves and Vorticity in Oceanic Flows’ (with KL Oliveras (Seattle University) and Christopher Curtis (San Diego State University)), National Science Foundation, USA, Sep 1, 2017-Aug 31, 2020
Sun and Heliosphere

Current State of Reduced Solar Activity: Intense Space Weather Events in the Inner Heliosphere

We present a study of 21 geomagnetic storms, occurred during 2011–2017 in association with the propagation of coronal mass ejections (CMEs). These storms are selected with the minimum storm intensity of -100 nT or less and are distributed from the maximum to the minimum of the weak solar cycle 24. We identify and investigate these storms driving CMEs (halo and partial halo CMEs) by combining EUV and white-light images in the near-Sun region, interplanetary scintillation images in between the Sun and the Earth (from the Ooty Radio Telescope), and in-situ measurements at the near-Earth orbit. These CMEs cover a wide range of initial speeds, ~180 to 2680 km/s. For about 50% of the CMEs, the fast initial speed at the near-Sun region does not correlate with the final speed at the near-Earth orbit. A comparison of travel time of CME to 1 AU with the observed initial/final speeds and estimated initial speed suggests that a large fraction of fast initial speeds could possibly be due to the sudden expansion of the CME into a relatively low pressure interplanetary medium. Most of the geomagnetic storms (i.e. 19 storms) have been caused by the strong intrinsic magnetic field of the CME and only 2 storms are produced by the sheath region between the arrival times of interplanetary shock and CME. A relatively less compression on the CME due to the low-speed background solar wind and a rapid radial decline of magnetic field could have also led to low geoeffectiveness. An examination of thermal and magnetic energy densities at 1 AU suggests that the propagation of CMEs corresponding to these storms has been influenced by the magnetic energy possessed by the CME. [P. K. Manoharan, K. Mahalakshmi, A. Johri, B. V. Jackson, D. Ravikumar, K. Kalyanasundaram, S. P. Subramanian, A. K. Mittal]

The intercalibration of IPS data sets from ISEE and Ooty observatories

The important advantage among the ISEE (Nagoya University, Japan) and Ooty IPS (National Centre for Radio Astrophysics, TIFR) observations is the same observing frequency of 327 MHz, which is best suited to probe solar wind density structures at heliocentric distances in the range of ~20–250 solar radii. The IPS measurements from these institutions have provided an impressive data base for nearly four solar cycles. The steerability of the Ooty Radio Telescope is useful to get simultaneous scintillation observations between Ooty and ISEE. The comparison of a large number of simultaneous measurements available between Ooty and ISEE yielded several interesting results: (a) Scintillation index curves have been established for ISEE observations; (b) For a given source, when the time difference between Ooty and ISEE observations is less than 30-min of time, the IPS power spectra from these observatories are compared and they look identical, which has been confirmed on more than one source. In excess of 90% of the simultaneous spectra match identically, which has exceed couple of hundreds, compare excellently well and the sensitivity difference between the telescopes has also been evidently shown. This result is a phenomenal one that two independent observatories separated by a large geographical position provide the identical results on solar wind. It essentially validates the importance of single station IPS measurements in space weather monitoring studies; (c) Despite the fact that more 90% of the simultaneous spectra match identically, few spectra between Ooty and ISEE show some remarkable difference, which has some comprehensive information on the solar wind structures passing along the individual line of sight to the radio source. More analysis will be taken up to explore the physical properties of the solar wind. [P. K. Manoharan, M. Tokumaru]
Propagation of Coronal Mass Ejections Observed During the Rising Phase of Solar Cycle 24

In this study, we investigate the interplanetary consequences and travel time details of 58 coronal mass ejections (CMEs) in the Sun-Earth distance. The CMEs considered are halo and partial halo events of width $>120^\circ$. These CMEs occurred during 2009 – 2013, in the ascending phase of the Solar Cycle 24. Moreover, they are Earth-directed events that originated close to the centre of the solar disk (within about $\pm 30^\circ$ from the Sun's centre) and propagated approximately along the Sun-Earth line. For each CME, the onset time and the initial speed have been estimated from the white-light images observed by the coronagraphs onboard the LASCO/SOHO space mission. These CMEs cover an initial speed range of $\sim$260 - 2700 km/s. For these CMEs, the associated interplanetary shocks (IP shocks) and interplanetary CMEs (ICMEs) at the near-Earth environment have been identified from in-situ solar wind measurements available at the OMNI data base. Most of these events have been associated with moderate to intense IP shocks. However, these events have caused only weak to moderate geomagnetic storms in the Earth's magnetosphere. The relationship of the travel time with the initial speed of the CME has been compared with the observations made in the previous Cycle 23, during 1996 - 2004. In the present study, for a given initial speed of the CME, the travel time and the speed at 1 AU suggest that the CME was most likely not much affected by the drag caused by the slow-speed dominated heliosphere. Additionally, the weak geomagnetic storms and moderate IP shocks associated with the current set of Earth-directed CMEs indicate magnetically weak CME events of Cycle 24. The magnetic energy that is available to propagate CME and cause geomagnetic storm could be significantly low. [S. M. Ibrahim, P. K. Manoharan, A. Shanmugaraj]

The Worldwide Interplanetary Scintillation (IPS) Stations (WIPSS) Network October 2016 Observing Campaign: Initial WIPSS data analyses

Interplanetary Scintillation (IPS) allows for the determination of velocity and a proxy for plasma density to be made throughout the corona and inner heliosphere. Where sufficient observations are undertaken, the results can be used as input to the University of California, San Diego (UCSD) three-dimensional (3-D) time-dependent tomography suite to allow for the full 3-D reconstruction of both velocity and density throughout the inner heliosphere. By combining IPS results from multiple observing locations around the planet, we can increase both the temporal and spatial coverage across the whole of the inner heliosphere and hence improve forecast capability. During October 2016, a unique opportunity arose whereby the European-based LOw Frequency ARray (LOFAR) radio telescope was used to make nearly four weeks of continuous observations of IPS as a heliospheric space-weather trial campaign. This was expanded into a global effort to include observations of IPS from the Murchison Widefield Array (MWA) in Western Australia and many more observations from various IPS-dedicated WIPSS Network systems. IPS data from LOFAR, ISEE, the MEXican Array Radio Telescope (MEXART), and, where possible, other WIPSS Network systems (such as LPI-BSA and Ooty Radio Telescope), have been used in this study and we present some initial findings for these data sets. We also make a first attempt at the 3-D reconstruction of multiple pertinent WIPSS results in the UCSD tomography. We will highlight some of the potential future tools that make LOFAR a very unique system to be able to test and validate a plethora of IPS analysis methods with the same set of IPS data. [Bisi et al.]

Space Weather Research – Indian perspective

Space weather, just like its meteorological counterpart, is of extreme importance when it comes to its impact on terrestrial near- and far-space environments. In recent years, space weather research has acquired an important place as a thrust area of research having implications both in space science and technology. The presence of satellites and other technological systems from different nations in near-Earth space necessitates that one must have a comprehensive understanding not only of the origin and evolution of space weather processes but also of their impact on technology and terrestrial upper atmosphere. To address this aspect, nations across the globe including India have been investing in research concerning Sun, solar processes and their evolution from solar interior into the interplanetary space, and their impact on Earth's magnetosphere-ionosphere-thermosphere system. In India, over the years, a substantial amount of work has been done in each of these areas by various agencies/institutions. In fact, India has been, and continues to be, at the forefront of space research and has ambitious future programs concerning these areas encompassing space weather. This review aims at
providing a glimpse of this Indian perspective on space weather research to the reader and presenting an up-to-date status of the same. [A. Bhardwaj, T. K. Pant, R. K. Choudhary, D. Nandy, P. K. Manoharan]

**Star and Pulsars**

**GMRT High Resolution Southern Sky (GHRSS) survey – A SKA pathfinder survey**

To bring out GMRT’s potential in blind search for pulsars, I formed a team and started the GHRSS survey. We have discovered 17 pulsars from this survey including one millisecond pulsar and two mildly recycled pulsars. The pulsar per square degree discovery rate of the GHRSS survey is one of the highest for the off-galactic-plane surveys. With upgraded GMRT (uGMRT) time-domain survey sensitivity is expected to improve at least by a factor of two in 300–500 MHz band. We have started phase-2 of the GHRSS survey with the upgraded GMRT and have discovered 2 pulsars in the pilot phase. With total 360 hours of survey done, we have a discovery rate of 1 pulsar per 20 hours. [B. Bhattacharyya, J. Roy, B. W. Stappers, T. Johnson, C. Llie, A. Lyne, M. Malenta, P. Weltevrede, Jayaram Chengalur, S. Cooper, M. Keith, S. Kudale, M. McLaughlin, S. M. Ransom, P. S. Ray, B. Kaur]

**Pulsars discovered by us with the GMRT between 2012–2017 from targeted and blind surveys. Fermi-directed discoveries – blue circles, GHRSS discoveries – red circles, most recent discoveries with GHRSS survey in last six months: red stars, sky coverage of Phase-1 of GHRSS survey – shaded region. Most of the pulsars discovered are |b| <20 degrees.**

**A long term timing study of three Rotating Radio Transients (RRATs)**

We present the longest-term timing study so far of three Rotating Radio Transients (RRATs) – J1819–1458, J1840–1419 and J1913+1330 – performed using the Lovell, Parkes and Green Bank telescopes over the past decade. We study long-term and short-term variations of the pulse emission rate from these RRATs and report a marginal indication of a long-term increase in pulse detection rate over time for PSR J1819–1458 and J1913+1330. For PSR J1913+1330, we also observe a two orders of magnitude variation in the observed pulse detection rates across individual epochs, which may constrain the models explaining the origin of RRAT pulses. In addition to bright RRAT pulses, we discovered a weak and persistent emission mode in PSR J1913+1330. [B. Bhattacharyya, A. G. Lyne, B. W. Stappers, P. Weltevrede, E. F. Keane, M. A. McLaughlin, M. Kramer, C. Jordan, C. Bassa]
Left panel: The timing residuals from the TOAs from the Lovell and the Parkes observations at L-band of the individual pulses from PSR J1819−1458 from post-glitch observations (relative to the model in Table 2) for ~ 3900 days i.e. ~ 11 years, showing that the majority of TOAs are located in three clearly identifiable bands with the accumulated arrival time histograms shown below. Right panel: The same residuals, but with the TOAs in the early and late bands fitted using offsets of −43.2±1.5 ms and +46.1±1.4 ms relative to the central band, to produce unbanded residuals, with the accumulated arrival time histogram shown below. The rms of the residuals subsequently decreases from 31.4 to 8.9 ms.

Discovery of coherent radio emission in a magnetic star

Observations of more than 350 stars in Milky Way has revealed 10% massive stars to be magnetic (Wade et al. 2012, 2016). The magneto-hydrodynamic simulations have revealed that the stellar wind properties of magnetic stars are modified in important ways as compared to the winds of non-magnetic stars. Studying the radio emission at different frequencies reveal the magnetic field topology of the star. We have taken up a systematic study of all magnetic massive stars at low frequencies with the GMRT and high frequencies with the VLA. Our observations of HD 133880 revealed Electron Cyclotron Coherent Emission (ECME) at GMRT frequencies (Das et al. 2018), whereas the star shows gyrosynchrotron emission at higher radio frequencies. This is only the second magnetic star in which coherent radio emission has been detected. Further studies are being carried out to understand the nature of ECME emission. Our work was reported in MNRAS Letters (Das et al. 2018, MNRAS Letters 474, L61). Now we are carrying out low frequency survey of a sample of fast rotating stars to explore ECME phenomenon. [Barnali Das, Poonam Chandra, Gregg Wade and Matt Shultz]

Pilot Pulsar survey with upgraded GMRT

Taking advantage of enhanced sensitivity due to wide-band receivers, commissioned in the recent upgrade of the GMRT, a pilot uGMRT pulsar survey was initiated towards the end of 2016. This pilot survey covered 300 square degrees of sky near the Galactic center in 512 pointings observed in band 3 of uGMRT (300 - 500 MHz). The observations for this pilot survey were completed by March 2017. In the last year, a new search pipeline was developed and implemented in the high performance cluster at NCRA, for analyzing these data. This pipeline was used to analyze all observations by January 2018. The analysis resulted in a large number of candidates. Further algorithms were developed to eliminate candidates due to radio frequency interference, mitigate the effects of strong satellite
interference from satellite such as Muos and other spurious periodicities, called "birdies". The pipeline was tuned based on detected birdies and a second pass of analysis was completed early this year. Apart from detecting known pulsars in the field, the survey has discovered the first new pulsar with the upgraded GMRT (as shown in the figure) which has been confirmed in follow-up observations. Several shortlisted candidates are being examined by our collaboration, some of which are likely to be confirmed as new pulsars. Further follow-up observations of the new pulsar and strong candidates are planned in future. Encouraged by these results, another pilot survey in band 4 (550-750 MHz) of a similar region of the sky is proposed this year to evaluate the most effective band of uGMRT for a future all-sky survey.

[Yashwant Gupta, Sushan Konar, Bhal Chandra Joshi, A. A. Deshpande, Abhimanyu Susobhanan, Alak Ray, Biplab Bijay, Biprteep Dey, Boris Kalita, Debades Bandopadhyay, Debasish Jena, Dipankar Bhattacharya, Gururaj Wagle, Manjar Bagchi, Mayuresh Surnis, Paramasivan Arumugam, Sajad Ahmad Bhat, Sanjay Kudale, Vishal Gajjar, Yogesh Maan]

Discovery plot from the search analysis pipeline of the pilot uGMRT pulsar survey, showing the detection of the first new pulsar with the uGMRT. The pulsar has a period of 442.5 ms and a dispersion measure of 69.1 pc/cc, and shows up clearly in both the frequency and time domain plots, with very good signal to noise ratio. Follow-up observations have confirmed this new discovery.

Indian Pulsar Timing Array Project

We initiated a project using the legacy Ooty Radio Telescope and the GMRT three years back to monitor a sample of 9 millisecond pulsars once every 20 days. These pulsar timing observations were aimed at establishing an Indian pulsar timing array experiment, similar to on-going international pulsar timing array (PTA) experiments. The main aim of PTAs is to detect nano-Hertz Gravitational waves. Around the same time, a parallel experiment to characterize and set-up precision timing with the upgraded GMRT (uGMRT) was started in November 2015. Both the experiments have now matured leading to improvements in observatory instrumentation and time and frequency standards. While the precision timing experiment with the uGMRT has demonstrated high precision timing capability of the uGMRT, the legacy experiment helped building our own timing solutions as well as development of analysis techniques for precision timing and Gravitational wave detection. The two experiments have been combined as a single Indian pulsar timing experiment (InPTA) since January 2018. This experiment monitors 20 pulsars once every fortnight and is yielding a timing precision of about 1 microsecond routinely for these pulsars. Throughout last year, monitoring observations were conducted with
the legacy GMRT and the uGMRT at band 3, 4 and 5 apart from high cadence observations with the ORT at 334.5 MHz. A collaboration of 15 astronomers from five institutions, led by NCRA-TIFR astronomers, is currently analyzing the data obtained. We are also developing the required software pipeline to handle data for a larger sample of pulsars in future. Since January this year, InPTA collaboration has become an associate member of International Pulsar Timing Array (IPTA) consortium, which combines the efforts of PTA experiments around the world, and many of our members are actively contributing in IPTA working groups. [Bhal Chandra Joshi, A. Gopakumar, Yashwant Gupta, M. Bagchi, M. A. Krishnakumar, P. Arumugasamy, P. K. Manoharan, Arun Naidu, M. Surnis, Abhimanyu S., S. Bethapudi, Shantanu Desai, Kishlay De, N. D. Batra, Yogesh Maan]

Augmenting Pulsar observing systems at ORT and pulsar monitoring program at ORT

A program for monitoring pulsars was initiated in February 2016 with funding from Science and Engineering Research Board, Department of Science and Technology, Government of India. New instrumentation consisting of Rubidium standard, Global positioning receivers, data storage servers and data acquisition machines were procured under this program in 2016 to 2017. An uninterrupted power supply to provide 24 hour backup for the new time and frequency standards was procured this year. All these instruments are commissioned and are used for monitoring pulsars with high precision pulsar timing. Currently, about 40 pulsars are monitored regularly under this program, which has resulted in about seven refereed publications in the last two years. [Bhal Chandra Joshi, P. K Manoharan, M. A. Krishnakumar]

Phase-resolved X-ray polarimetry of the Crab pulsar with the AstroSat CZT Imager

The Crab pulsar is a typical example of a young, rapidly spinning, strongly magnetized neutron star that generates broad-band electromagnetic radiation by accelerating charged particles to near light speeds in its magnetosphere. Details of this emission process so far remain poorly understood. Measurement of polarization in X-rays, particularly as a function of pulse phase, is thought to be a key element necessary to unravel the mystery of pulsar radiation. However, such measurements are extremely difficult. To date, Crab is the only pulsar to have been detected in polarized X-rays and the measurements have not been sensitive enough to adequately reveal the variation of polarization characteristics across the pulse. Soon after the launch of the first Indian multi-wavelength astronomy satellite AstroSat, this pulsar was observed repeatedly with Cadmium-Zinc-Telluride Imager in coordination with TIFRs two ground based radio telescopes - the ORT and the GMRT. This resulted in the most sensitive measurements to date of polarized hard X-ray emission from the Crab pulsar and nebula in the 100-380 keV band. The radio observations with the ORT and the GMRT provided accurate pulse ephemeris allowing for the first time a phase resolved measurements of hard X-rays of this pulsar. We confirm with high significance the earlier indication of a strongly polarized off-pulse emission. However, we also find a variation in polarization properties within the off-pulse region. In addition, our data hint at a swing of the polarization angle across the pulse peaks. This behaviour challenges the existing theoretical models of high-energy emission from pulsars. [S. V. Vadawale, T. Chattopadhyay, N. P. S. Mithun, A. R. Rao, D. Bhattacharya, A. Vibhute, V. B. Bhalerao, G. C. Dewangan, R. Misra, B. Paul, Avishek Basu, Bhal Chandra Joshi, S. Sreekumar, E. Samuel, P. Priya, P. Vinod, S. Seetha]

Coordinated ORT-GMRT-ASTROSAT observations of PSR B0531+21 for calibration of timing offsets of CZTI instrument

Average pulse profile of PSR B0531+21 obtained using phase coherent average over all data with different instruments used in this study. The data were aligned using the offsets estimated in this study. The larger peak is called as main-pulse, while the smaller peak is referred as interpulse. The panels show the average profiles obtained with FERMI archival data, the CZTI, the GMRT and the ORT from bottom panel to top respectively. The radio profile were obtained with the GMRT at 1390 MHz and with the ORT at 334.5 MHz.
CZTI is a hard X-ray telescope aboard Indian multi-wavelength mission AstroSat and operates over an energy range of 20-380 keV. The timing offset introduced in the data acquisition pipeline of this instrument is unknown and is required for time alignment of high energy time-series with those from ground based observatories. Soon after the launch of AstroSat mission, we conducted coordinated observations with the legacy GMRT at 1390 MHz and the ORT at 334.5 MHz of the bright X-ray and radio pulsar B0531+21 (Crab pulsar) to calibrate the timing offsets. PSR B0531+21 is a well-studied bright pulsar with nearly aligned radio and hard X-ray pulse profiles. Observations with daily cadence were carried out at the ORT to obtain good timing solutions. Analysis of these data and archival data from FERMI-LAT mission allowed full characterization of timing noise and Dispersion Measure variation seen in this pulsar. After correcting for these effects, we have determined relative offset of ASTROSAT-CZTI with respect to the ORT and the GMRT as -29 and -4 milliseconds respectively.

The resultant aligned profile of PSR B0531+21 from radio to high energies is shown in the figure. [Avishek Basu, Bhal Chandra Joshi, Dipankar Bhattacharya, A. R. Rao, A. Naidu, M. A. Krishnakumar, Prakash Arumugsamy, Santosh Vadawale, P. K. Manoharan, G. C. Dewangan, N. P. S. Mithun]

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**GMRT Galactic Plane Pulsar and Transient Survey and the Discovery of PSR J1838+1523**

We carried out a survey covering about 10% of the region between Galactic longitude 45 deg < l < 135 deg and Galactic latitude 1 deg < |b| < 10 deg with a dwell time of 1800 s. Last year, we reported the results of this blind pulsar survey carried out with the Giant Metrewave Radio Telescope at 325 MHz, which resulted in the detection of 28 pulsars. One of these, PSR J1838+1523 was previously unknown and has a period of 549 ms and a dispersion measure of 68 pc cm$^{-3}$. We also reported the timing solution of this pulsar obtained from multi-frequency timing observations carried out with the GMRT and the ORT. The measured flux density of this pulsar is 4.3 ± 1.8 and 1.2 ± 0.7 mJy at 325 and 610 MHz respectively. This implies a spectral index of -2 ± 0.8, thus making the expected flux density at 1.4 GHz to be about 0.2 mJy, which would be just detectable in the high frequency pulsar surveys like the Northern High Time Resolution Universe pulsar survey. This discovery underlines the importance of low frequency pulsar surveys in detecting steep spectrum pulsars, thus providing complementary coverage of the pulsar population. [M. P. Surnis, Bhal Chandra Joshi, Maura A. McLaughlin, Duncan R. Lorimer, Krishnakumar M. A., P. K. Manoharan, Arun Naidu]
Observations of high Dispersion Measure pulsars with Arecibo telescope

The inhomogeneities in the inter-stellar medium scatter the pulsed emission from radio pulsars broadening the observed pulse. Measurements of this pulse scatter broadening constrains the nature of turbulence in the inter-stellar medium and its spectrum as this is related to a strong evolution of pulse scatter broadening with observing frequency. This evolution is well studied for pulsars with Dispersion Measure (DM) less than 500, particularly in our recent investigations with the ORT and the uGMRT. However, very few measurements are available for pulsars with DM greater than 500. Last year, we proposed and obtained observations on a sample of 9 such pulsars with the Arecibo telescope. DM of these pulsars range from 512 to 1274 pc/cc. We also obtained archival data from the Parkes radio telescope and the GMRT to enhance the final sample, which consisted of 29 pulsars with DM ranging 198 to 1274 pc/cc. This is the largest statistically significant sample of high DM pulsars, which has been investigated so far. In our preliminary results from analysis of these data, we find that DMs of some of the pulsars were different from that reported in the literature. These observations indicate that frequency scaling index of pulse scatter-broadening is consistent with Kolmogorov spectrum even for high DM pulsars contrary to what was reported about two decades back. Work is in progress to quantify evolution of pulse scatter-broadening with frequency and interpretation of these new results [M. A. Krishnakumar, Bhal Chandra Joshi, P. K. Manoharan]

Observations of scattering of low DM pulsars with LOFAR

Scattering in the inter-stellar medium causes a severe broadening of pulsed emission from radio pulsars at frequency below 300 MHz. At the same time, pulse scatter-broadening also increases with Dispersion Measure (DM) of pulsar. While this leads to non-detection of pulsed emission in higher DM pulsars at low frequencies, lack of significant pulse scatter-broadening for pulsars with DM less than 50 pc/cc at observation frequencies greater than 300 MHz makes measurements of this effect difficult for such pulsars. As very few measurements were available for such pulsars, we observed a sample 8 pulsars using low band array of LOFAR last year between 30-80 MHz. We also obtained archival data for 10 pulsars observed using LWA (10-88 MHz) and 14 pulsars, which were observed using high band array (110-190 MHz) of LOFAR. With this unique sample of 29 pulsars covering a range of DM between 14 to 130 pc/cc, we have increased the sample of such measurements by about 60 %. Our preliminary results hint at a frequency dependence of frequency scaling index of pulse scatter-broadening, with this index much steeper than expected Kolmogorov spectrum [M. A. Krishnakumar, Yogesh Maan, Bhal Chandra Joshi, P. K. Manoharan]

Simultaneous multi-frequency observations of single pulses from pulsars

There is a small class of pulsars, which shows pulse nulling, sub-pulse drifting and profile mode changes. The best example of this class are PSRs B0031-07 and B2319+60. In a recent study, we found two similar interesting pulsars. We have used the unique capability of the uGMRT to conduct simultaneous multi-frequency observations of PSRs J1822-2256 and J1901-0906 covering a frequency range from 250 to 1500 MHz to obtain high sensitivity data on single pulses for these pulsars. For PSR J1822-2256, no emission is detected in about 10 % of pulses. At least two drift modes and a possibly third rare mode, occur for 66, 21 and 2 % pulses respectively (P3 ~ 17, 7.5 and 5 P0 respectively). The three drift modes and the nulls occur concurrently from 250 to 1500 MHz. Modal average profiles are distinct with their widths increasing with drift rate. These sub-pulse drift related profile mode changes can provide independent probes of beam geometry and polar gap physics. In addition, we also conducted observations of PSR J0934-5249 over 250 to 1500 MHz to investigate the memory of sub-pulse drift with pulse nulling. The analysis of this unique data set is currently in progress [Bhal Chandra Joshi, Arun Kumar Naidu, Vishal Kumar Gajjar, G. A. E. Wright]

Observations of largest glitch in Crab pulsar

The largest ever detected glitch in Crab pulsar (PSR B0531+21) on MJD 58064 observed with the ORT
Crab pulsar (PSR B0531+21) is monitored about once every day as part of our routine pulsar monitoring program at the Ooty Radio Telescope. These observations are carried out at the central frequency of 326.5 MHz, with a 16-MHz pass-band. Our monitoring detected the largest glitch reported in this pulsar so far at MJD 58064. Our estimate of the fractional spin up is about (0.47+0.07) E-6. The phase connected residuals with the pre-glitch solutions are shown in the figure. [M. A. Krishnakumar, Bhal Chandra Joshi, Avishek Basu, P K Manoharan]

**Detection of long nulls in PSR B1706-16, a pulsar with large timing irregularities:**

Single pulse observations, characterizing in detail, the nulling behaviour of PSR B1706-16 are being reported for the first time in this paper. Our regular long duration monitoring of this pulsar reveals long nulls of 2-5 h with an overall nulling fraction of 31 ± 2 per cent. The pulsar shows two distinct phases of emission. It is usually in an active phase, characterized by pulsations interspersed with shorter nulls, with a nulling fraction of about 15 per cent, but it also rarely switches to an inactive phase, consisting of long nulls. The nulls in this pulsar are concurrent between 326.5 and 610 MHz. Profile mode changes accompanied by changes in fluctuation properties are seen in this pulsar, which switches from mode A before a null to mode B after the null. The distribution of null duration in this pulsar is bimodal. With its occasional long nulls, PSR B1706-16 joins the small group of intermediate nullers, which lie between the classical nulling pulsars and the intermittent pulsars. Similar to other intermediate nullers, PSR B1706-16 shows high timing noise, which could be due to its rare long nulls if one assumes that the slowdown rate during such nulls is different from that during the bursts. [A. Naidu, B.C. Joshi, P.K. Manoharan, M.A. Krishnakumar]

**Detection of radio emission from the gamma-ray pulsar J1732-3131 at 327 MHz**

Although originally discovered as a radio-quiet gamma-ray pulsar, J1732-3131 has exhibited intriguing detections at decimeter wavelengths. We report an extensive follow-up of the pulsar at 327 MHz with the Ooty radio telescope. Using the previously observed radio characteristics, and with an effective integration time of 60 h, we present a detection of the pulsar at a confidence level of 99.82 per cent. The 327 MHz mean flux density is estimated to be 0.5-0.8 mJy, which establishes the pulsar to be a steep spectrum source and one of the least luminous pulsars known to date. We also phase-aligned the radio and gamma-ray profiles of the pulsar, and measured the phase-offset between the main peaks in the two profiles to be 0.24 ± 0.06. We discuss the observed phase-offset in the context of various trends exhibited by the radio-loud gamma-ray pulsar population, and suggest that the gamma-ray emission from J1732-3131 is best explained by outer magnetosphere models. Details of our analysis leading to the pulsar detection, and measurements of various parameters and their implications relevant to the pulsar’s emission mechanism are presented. [Y. Maan, M.A. Krishnakumar, A.K. Naidu, S. Roy, B.C. Joshi, M. Kerr, P. K. Manoharan]

**GMRT monitoring of the Black Hole X-ray Binary V404 Cygni during its 2015 outburst**

We have used the GMRT to monitor the black hole binary system V404 Cygni during its flaring outburst in June 2015, at low frequencies, <= 1.4 GHz. We find the low-frequency radio emission of V404 Cygni to be extremely bright and fast-decaying in the outburst phase, with an inverted spectrum below 1.5 GHz and an intermediate X-ray state. The radio emission settles to a weak, quiescent state 11 days after the outburst, with a flat radio spectrum and a soft X-ray state. Combining the GMRT measurements with flux density estimates from the literature, we identified two peaks in the radio spectrum at 1.5-3 GHz on June 26.9 UT, indicating the presence of two synchrotron self-absorbed emitting regions, perhaps arising from two radio outbursts. We used the measured flux density at the turnover frequency with the assumption of equipartition of energy between the particles and the magnetic field to infer the jet radius, the magnetic field, the minimum total energy and the transient jet power. The relatively low value of the jet power, despite V404 Cygni’s high black hole spin parameter, suggests that the radio jet power does not correlate with the spin parameter. A paper on the results has been published in Astrophysical Journal. [Nissim Kanekar, Poonam Chandra]
GMRT detection of the Galactic Warm Neutral Medium towards B0438-436

We have used the GMRT to carry out a deep search for Galactic HI 21cm absorption towards the quasar B0438-436, yielding the detection of wide, weak absorption, with a very low peak optical depth, ~ 0.001. Comparing this with the HI column density measured in the Parkes Galactic All-Sky Survey gives a column density-weighted harmonic mean spin temperature of $3760 \pm 365$ K, one of the highest measured in the Milky Way. This is consistent with most of the HI along the sightline arising in the stable warm neutral medium (WNM). The low peak HI 21cm optical depth towards B0438-436 implies negligible self-absorption, allowing a multi-Gaussian joint decomposition of the HI 21cm absorption and emission spectra. This yields a gas kinetic temperature of $\leq 4910 \pm 1900$ K, and a spin temperature of $1000 \pm 345$ K for the gas that gives rise to the HI 21cm absorption. Our data are consistent with the HI 21cm absorption arising from either the stable WNM, with spin temperature much lower than the kinetic temperature, and little penetration of the background Lyman-alpha radiation field into the neutral hydrogen, or from the unstable neutral medium, with spin temperature approximately equal to the kinetic temperature. [Nissim Kanekar, Narendra Nath Patra, Jayaram Chengalur, Nirupam Roy]

Extra Galactic Astronomy and Cosmology

Discovery of a shock in a low mass galaxy cluster

Radio relics at the peripheries of high mass galaxy clusters are routinely used to trace shocks. However occurrence of such shocks in low mass clusters is unknown. We have discovered a radio relic that traces peripheral shock in a low-mass galaxy cluster PLCK G200.9-28.2 using the Giant Metrewave Radio Telescope and the Karl G. Jansky Very Large Array. This cluster is the lowest mass cluster known to have radio detected shock at its periphery. The relic has a projected size of $1 \times 0.28$ Mpc, an arc-like morphology and is located at 0.9 Mpc from the X-ray brightness peak in the cluster. Under the assumption of diffusive shock acceleration, the radio spectral index implied Mach number of $3.3 \pm 1.8$ for the shock. Based on this cluster we have put forward the use of pressure and density offset to find signatures of shocks in low mass clusters. [Ruta Kale, D. R. Wik, S. Giacintucci, T.Venturi, G.Brunetti, R.Cassano, D. Dallacasa, de Gasperin, F.]

An observation simulator to plan observing strategies with the GMRT, uGMRT and SKA

We have developed a radio observation simulator with the purpose of planning observing strategies tailored for searching diffuse extended radio sources. This was used to simulate observations of extended radio sources such as radio halos in galaxy clusters with the GMRT and the Upgraded GMRT. The recovery in flux density and in morphology of the model source was quantified in a variety of observing cases with changing source properties and the uv-coverage. We showed that the Upgraded GMRT will provide a factor of 2 better recovery of extended sources as compared to the GMRT for the same observing duration. Simulations of observations with the Square Kilometre Array were also carried out to show the effect of changing configurations on the capabilities of imaging extended sources. This simulator tool is made available upon request to the community. [D.K. Deo, Ruta Kale]

Prospects for AGN feedback and cosmological studies using the Square Kilometre Array

The Square Kilometre Array (SKA) is the next generation radio telescope that is expected to reach unprecedented sensitivities. We have presented the
science cases in the field of feedback from the active galactic nuclei (AGN) in galaxy clusters and cosmology using the SKA. The radio emission in brightest cluster galaxies coming from, both, AGN and star formation will be detectable for galaxy clusters up to redshifts of 1.4 allowing to study the role of the intra-cluster medium in triggering of AGN in the central galaxy. [A. Ahangar, Ruta Kale, S. Majumdar, B .B. Nath, M. Pandge, P. Sharma, M. A. Malik, S. Raychaudhury]

**ALMA mapping of CII 158-micron emission from a damped Lyman-alpha absorber at z=4.2**

We have used the Atacama Large Millimeter/sub-millimeter Array (ALMA) to carry out high spatial resolution studies of ionized carbon CII 158-micron emission of a damped Lyman-alpha absorber at z=4.2. This has allowed us to measure the velocity field of a high-redshift, absorption-selected galaxy for the first time, demonstrating clearly that this is a massive rotating disk, similar to the Milky Way. We also find evidence for sub-structure in the velocity field, possibly indicative of merging clumps; around two-thirds of the CII 158-micron emission arises from the disk structure, and one-third from structures that are not in regular rotational motion. [Nissim Kanekar, M. Neeleman, J. X. Prochaska, C. L. Carilli, M. Rafelski]

**ALMA detections of CO emission in high-redshift damped Lyman-alpha absorbers**

We have used the Atacama Large Millimeter/sub-millimeter Array (ALMA) to detect CO emission from high-metallicity damped Lyman-alpha systems (DLAs) at z = 0.5-2.6, allowing us to measure the molecular gas masses of the absorbers. The inferred molecular gas masses are very large, 2-50 times larger than that of the Milky Way, and the impact parameters are also large, 15-40 kpc. The DLAs at intermediate redshifts, z=0.5-0.8, have very large gas fractions and low star formation efficiencies for their star formation rates and stellar masses, very unlike emission selected galaxies at similar redshifts and the local Universe. Their relatively low SFRs, despite the large molecular gas reservoirs, may indicate a transition in the nature of star formation at intermediate redshifts, after the peak epoch of galaxy assembly in the Universe. A paper on the results has been published in Astrophysical Journal Letters, and a second has been published in Monthly Notices of the Royal Astronomical Society. The two DLAs with CO detections at z=2.2 and z=2.6 have high molecular gas masses, and high star formation rates, similar to colour-selected star-forming disk galaxies at z~2. However, despite the strong CO emission indicating a large mass of cold gas, a Giant Metrewave Radio Telescope search for HI 21cm absorption from one of the DLAs yielded a non-detection of HI 21cm absorption, implying a high spin temperature. This emphasizes the multi-phase nature of the gas along the absorption sightline. A paper on these results has been published in Astrophysical Journal Letters, and a second paper has now been submitted to Monthly Notices of the Royal Astronomical Society. [Nissim Kanekar, J. X. Prochaska, M. Neeleman, M. Zwaan, P. Moller, L. Christensen Johan P. U. Fynbo]

**ALMA detection of molecular absorption from a gravitational lens at z=0.765**

We have used ALMA to detect redshifted CO and HCO+ absorption at z=0.765 from the spiral gravitational lens towards the quasar J0134-0931. This is only the fifth detection of molecular absorption at cosmological distances. The CO J=2-1 and HCO+ J=2-1 lines are seen along two different lines of sight to lensed images of the background quasar. The lines of sight are separated by ~0.7”, corresponding to 5 kpc in the lens plane. The absorption lines through the two sightlines have a velocity separation of 215 km/s, possibly representing rotational motion in the lens system. The absorption profiles are wide, 200 km/s between line peaks, suggesting that the absorption occurs in a highly inclined disk galaxy with a flat rotation curve and a cloud-cloud velocity dispersion of ~30 km/s. The CO and HCO+ column densities are normal for diffuse molecular clouds towards one of the lensed images, but significantly higher towards the other; it appear plausible that the second line of sight probes denser molecular gas than is normally the case for absorption in disk galaxies. [Nissim Kanekar, Tommy Wickind Francoise Combes]

**Simulated predictions for HI at z=3.35 with the Ooty Wide Field Array**

Foreground removal is the most important step in detecting the large-scale redshifted H I 21-cm signal. Modelling foreground spectra is challenging and is further complicated by the chromatic response of the telescope. A multifrequency angular power spectrum (MAPS) estimator for use in a survey for redshifted H I 21-cm emission from z ~ 3.35 with the upcoming Ooty Wide Field Array (OWFA), was developed. We show via simulations that the MAPS estimator recovers
the input angular power spectrum accurately and that the instrument response to the foregrounds dominates the systematic errors in the recovered foreground power spectra. [V. R. Marthi, S. Chatterjee, Jayaram Chengalur, S. Bharadwaj]

**Angular Momentum of Dwarf Galaxies**

The specific baryonic angular momentum of five gas-rich dwarf galaxies was derived. The relation between the specific baryonic angular momentum ($j$) and the total baryonic mass ($M$) for these galaxies was compared with that found for spiral galaxies. The combined sample explores the $j$-$M$ plane over three orders of magnitude in baryon mass. It is found that the dwarf galaxies have significantly higher specific angular momentum than expected from the relation found for spiral galaxies. It is suggested that this difference could arise due to one or more of the following: a lower baryon fraction in dwarf galaxies, particularly that arising from preferential outflows low angular momentum gas as found in high-resolution simulations that include baryonic feedback; ‘cold mode’ anisotropic accretion from cosmic filaments. This work reinforces the importance of the $j$-$M$ plane in understanding the evolution of galaxies. [Aditya Chowdhury, Jayaram Chengalur]

**Stringent constraints on fundamental constant evolution from conjugate satellite OH lines**

We have used the Arecibo Telescope to carry out one of the deepest-ever integrations in radio astronomy, targeting the redshifted conjugate satellite OH 18cm lines at $z=0.247$ towards PKS1413+135. The satellite OH 1720 MHz and 1612 MHz lines are respectively in emission and absorption, with exactly the same line shapes due to population inversion in the OH ground state levels. Since the 1720 and 1612 MHz line frequencies have different dependences on the fine structure constant and the proton-electron mass ratio, the perfect cancellation of the sum of the line optical depths makes them immune to systematic effects in probing putative changes in the fundamental constants with cosmological time. A non-parametric analysis of our new Arecibo data yields the most stringent present constraint on fractional changes in the fine structure constant from astronomical spectroscopy, and with no known systematic effects. A paper on the results has been published in Physical Review Letters. [Nissim Kanekar, Tapasi Ghosh Jayaram Chengalur]

**A candidate sub-parsec binary black hole in the Seyfert galaxy NGC 7674**

We discovered the nearest supermassive binary black hole candidate in the Seyfert galaxy NGC 7674 with the Very Long Baseline Array (VLBA). These results were published in Nature Astronomy. [Preeti Kharb, D. V. Lal, D. Merritt]

**Estimating the magnetic field properties of disk galaxies from rotation measure synthesis.**

Deriving the Faraday rotation measure (RM) of quasar absorption line systems, which are tracers of high-redshift galaxies intervening background quasars, is a powerful tool for probing magnetic fields in distant galaxies. Statistically comparing the RM distributions of two quasar samples, with and without absorption line systems, allows one to infer magnetic field properties of the intervening galaxy population. We have derived the analytical form of the probability distribution function (PDF) of the RM produced by a single galaxy with an axisymmetric large-scale magnetic field. We further determined the PDF of RM for a random sight line traversing each galaxy in a population with a large-scale magnetic field prescription. We find that the resulting PDF of RM is dominated by a Lorentzian with a width that is directly related to the mean axisymmetric large-scale field strength of the galaxy population, if the dispersion within the population is smaller than the mean. Provided that RMs produced by the intervening galaxies have been successfully isolated from other RM contributions along the line of sight, our simple model suggests that the mean large-scale field in galaxies.
probed by quasar absorption line systems can be measured within ~50% accuracy without additional constraints on the magneto-ionic medium properties of the galaxies. We also considered quasar sample selection criteria that are crucial to reliably interpret observational data, and argue that within the limitations of the current database of absorption line systems, high-metallicity damped Lyman-alpha absorbers are best suited to study galactic dynamo action in distant disc galaxies. A paper on the results has been published in Monthly Notices of the Royal Astronomical Society. [Nissim Kanekar, A. Basu, S. A. Mao, A. Fletcher, A. Shukurov, V. Vacca, H. Junklewitz]

Radio emission from NS-NS merger

On August 17, 2017, the Advanced Laser Interferometer Gravitational Wave Observatory (Advanced LIGO), along with Advanced VIRGO data detected a gravitational wave event (GW170817) from the merger of two neutron stars (NS-NS merger) at a distance of 40 Mpc. Being the the NS-NS merger event discovered, it was followed by almost all known telescopes on the Earth and the space looking for electromagnetic (EM) signatures, including X-ray, ultra-violet, optical, infrared, and radio waves. We started following up the event with the Giant Metrewave Radio Telescope (GMRT). Even though the early radio observations at GMRT resulted in a non-detection, this provided constraints on the immediate environments, and hence GMRT played a key role in understanding jet physics and refining models of radio emission from the remnant formed by the merging neutron stars (Hallinan et al 2017). With our continued follow up, eventually we discovered the lowest frequency emission from the GW event at the GMRT 610 MHz frequency (Mooley et al. 2018, Nature). The GMRT observations, along with the Karl G. Jansky Very Large Array (VLA) and the Australian Telescope Compact Array (ATCA) suggested that the radio light curve of GW170817 was inconsistent with emission from a collimated jet viewed off-axis, instead requiring a quasi-spherical, mildly relativistic outflow, consistent with the cocoon model. [Greg Hallinan, Kunal Mooley, Kishaley De .... Poonam Chandra, ... Mansi Kasliwal]

Supernovae interacting with immediate environments

In a supernova explosion, much of a star’s material (ejecta) is expelled with a velocity up to 30,000 km/s, driving a strong shock wave into the surrounding circumstellar medium (CSM). The shock interaction with the CSM gives rise to radio and X-ray emission. The radio emission is absorbed depending upon the properties of the surrounding medium and is most effectively traced at low radio frequencies as it varies with wavelength as \( \lambda^2 \). My graduate student A. J. Nayana is carrying out low frequency studies of core collapse supernovae with the GMRT towards her thesis. She observed more than a dozen core collapse supernovae and detected radio emission from 6 of them. She has modelled the long term follow up of SN 2004dj under this project. The data indicated inverse-Compton cooling at early times. Our observations have revealed that the SN exploded in a high density medium, and constrained the mass loss rate of the progenitor star. [A. J. Nayana, Poonam Chandra]

Gamma Ray Bursts: GRB 171205

While a typical GRB explosion lasts from milliseconds to a few minutes, the afterglow emission due to interaction of the jet with the surrounding medium can be seen for much longer. A major advantage of radio afterglow emission is that, due to slow evolution it peaks at much later time and lasts longer, for months or even years, presenting the possibility of following the full evolution of the fireball emission from the very beginning till the non-relativistic phase, when the geometry of collimation becomes insignificant and
energetics can be determined more accurately. We are carrying out low frequency radio studies of the brightest GRBs with the GMRT. We have observed more than 15 GRBs at GMRT low frequencies under various GTAC and DDT proposals. We discovered radio emission from GRB 171205. More observations are being taken in the upcoming GMRT cycle. [Poonam Chandra, Dipankar Bhattacharya, A. J. Nayana, S. Bradley Cenko, Alessandra Corsi]  

**Double-peaked Emission Lines Due to a Radio Outflow in KISSR 1219**

1.5 GHz VLA and (bottom) VLBA radio contour image of KISSR 1219 showing a one-sided core-jet structure that could be a result of Doppler boosting effects in the observed jet luminosity.

A small fraction of active galactic nuclei (AGN) exhibit splits in their emission line peaks; these are referred to as double-peaked emission-line AGN (DPAGN). DPAGN are potential candidates for binary AGN. We have been looking at several DPAGN with the VLBA which can detect radio emission on parsec-scales in these nearby AGN. Our study revealed the presence of one-sided core-jet structure in the DPAGN and Seyfert 2 galaxy KISSR 1219. A one-sided jet is also observed on kiloparsec-scales with the Very Large Array (VLA). Doppler boosting effects due to jet speeds of $\gtrsim 0.55c$ to $\gtrsim 0.25c$, going from parsec to kiloparsec scales, and a jet inclination $\gtrsim 50^\circ$ can explain the jet one-sidedness in this source. A blue-shifted broad emission line component in [O III] was also indicative of an outflow in the emission line gas while the [O I] doublet lines suggested the presence of shock-heated gas. A detailed line ratio study using the MAPPINGS III code further suggested that a shock+precursor model could explain the line ionization data well. Overall our data suggested that the radio outflow in KISSR 1219 was pushing the emission line clouds, both ahead of the jet and in a lateral direction, giving rise to the double peak emission line spectra. [Preeti Kharb, S. Subramanian, S. Vaddi, M. Das, Z. Paragi]  

**Radio-emitting narrow-line Seyfert 1 galaxies in the JVLA perspective**

A radio survey of 74 narrow-line Seyfert 1 galaxies (NLS1s) was carried out with the Very Large Array (VLA) at 5 GHz. NLS1s are a special sub-class of AGN that resemble Seyfert galaxies in most respects but have narrower permitted lines in their spectra compared to Seyferts. This survey is currently the largest survey aimed at imaging the radio continuum in NLS1s. We compared the radio properties of three different sub-samples: radio-quiet NLS1s (RQNLS1s), steep-spectrum radio-loud NLS1s (S-NLS1s), and flat-spectrum radio-loud NLS1s (F-NLS1s). We found that these sub-classes had different radio morphologies with F-NLS1s being more compact, and RQNLS1s showing diffuse emission on kpc scales. We concluded that F-
NLS1s might be young blazars, and S-NLS1s may form a part of the parent population of F-NLS1s. [M. Berton, E. Congiu, E. Jarvela, R. Antonucci, P. Kharb, M. Lister, A. Tarchi, A. Caccianiga, S. Chen, L. Foschini, A. Lahteenmaki, J. Richards, S. Ciroi1, V. Craeco, M. Frezzato, G. La Mura, P. Rafanelli]

**Inhomogeneous Shock Structure crossing a dense shell in a supernova**

We observed a Type Ib supernova (SN) Master OT J120451.50+265946.6 with the GMRT at multiple bands and multiple epochs. We modelled the radio observations with the synchrotron radiation emanating due to the SN ejecta interacting with the circumstellar medium created by a wind due to the mass loss from the progenitor star. The low frequency GMRT observations in the optically thick phase reveal inhomogeneities in the structure of the radio emitting region. The GMRT observations combined with the Karl G. Jansky Very Large Array data indicate that the inhomogeneous radio emitting shock is passing through a dense shell during the early epochs, around first 100 days. Our observations reveal the importance of obtaining well-sampled low-frequency data in order to understand the intricate nature of the radio emission from young supernovae. [A. J. Nayana, Poonam Chandra, Claes-Ingvar Bjornsson, Peter Lundqvist, Francesco Taddia, Alak Ray]

**Radio emission from Type Ia supernovae**

We still lack knowledge about the origin of thermonuclear supernovae (SNe Ia), despite their huge cosmo-logical and galactochemical importance. There are two probable progenitor systems for SNe Ia. The first one, known as single degenerate (SD) channel, consists a single white dwarf (WD), which by accreting matter from a nondegenerate donor star explodes as a SN. The second channel, called double degenerate (DD), is composed of two spiraling WDs. One of the ways to discriminate the progenitor channels is to search for circumstellar material (CSM). The flux of radio emission from the SN shocks are roughly proportional to the density of the surrounding medium. Thus it is possible to trace the CSM through radio observations. We have started a project to explore radio emission from Type Ia SNe and in this GMRT cycle, we plan to obtain observations of four nearby type Ia SNe, SNe 1937C, 1885B, 1972E and 2014J, which are around 4 to 123 years of old. [Esha Kundu, Poonam Chandra, Peter Lundqvist, Miguel Perez-Torres]

**Square Kilometre Array**

NCRA leads Indian participation in the international SKA project

The Square Kilometre Array (SKA) is the most ambitious international radio astronomy project attempted to date. It aims to build a telescope with 1 million square metres of collecting area, covering a large frequency range from about 50 MHz to 10 GHz, in a radio quiet region of the globe. This will result in an instrument that is at least 30 times more sensitive than the best today, capable of cutting edge science in several aspects of astronomy and astrophysics. As of today, eleven of the major radio astronomy practicing nations are collaborating in this project, which entered the design phase from November 2013 onwards, expected to last till middle of 2019. Construction of the telescope will then begin towards end of 2020, with early science expected by 2023-24.

India (represented by NCRA) is an active participant in the SKA since the early days, and became a Full Member of the SKA Organisation in October 2015. The SKA India Steering Committee, a high level committee set-up by the Department of Atomic Energy, provides guidance and monitoring of the overall SKA activities in India. The SKA India Consortium (SKAIC), created in February 2015, to bring together under one umbrella all organisations in India interested in SKA activities and coordinate the SKA related activities across the country, has increased its sphere of activities during this year. In addition to the main Executive Council of the SKAIC, two sub-committees of the SKAIC are also active: one to coordinate all the science related activities and another to coordinate all the technical activities.

Meanwhile, Indian involvement in the design phase activities of the SKA continued, with NCRA leading a collaboration of members from 7 different SKA member countries for the work on the design of the Telescope Manager – a sophisticated monitor & control system for the SKA, which will be like the brain and central nervous system of the observatory. The Telescope Manager consortium successfully completed several new milestones during this year, including the prequalification test for readiness to complete the
Critical Design Review (CDR) and submission of the final set of design documents. The CDR meeting is scheduled for April 2018 with the timeline for closure of the TM design phase slated for June-July 2018. There was a major status update on the activities of the various consortia at the Annual SKA Engineering meeting in Rotterdam, The Netherlands in June 2017. NCRA also continues to be involved to a smaller extent in the Signal & Data Transport work package. Many of these SKA activities are being carried out in active collaboration with partners from Indian industry.

Along with the above, science activities related to the SKA continue to gain momentum in India. The SKA India Science Working Groups have been actively pursuing the development of the SKA India science case, as well as early activities related to theoretical and simulation studies, and pilot experiments with pathfinder and precursor facilities. Some of the highlights for this year are:

1. Following the publication of the SKA India science case in early 2017, the SKA India consortium organised a one-day SKA science workshop along with the annual meeting of the Astronomical Society of India in February 2018 in Hyderabad. Following this, work has started towards writing up the SKA India science case for the Detailed Project Report (DPR) to be prepared for submission to Government of India for approval of participation of India in the construction phase of SKA.

2. Furthermore, various SKA-India SWGs have been exploring options to use existing facilities to prepare for SKA science. In this regard, some of the groups have already formed collaborations and applied for time in the GMRT. Updates and results from these activities are expected in the near future.

[Sanjay Kudale, Jayaram Chengalur]
improvements in the support electronics. For the fibre-optic system, there is a new scheme for transfer of broadband signals from each antenna to the central receiver room, while maintaining the availability of the existing system for transfer of narrow band signals with IF carriers.

For the GMRT feeds and front-end receivers, the following has been achieved:

1. The installation of the wideband feeds and matching front-end receivers was completed for all 30 antennas, for all the main 4 frequency bands of the upgraded GMRT: 130-260 MHz (Band-2), 250-500 MHz (Band-3), 550-850 MHz (Band-4) and 1000-1450 MHz (Band-5). This marked a major milestone completion for the upgraded GMRT. [Bhandari Hanumanth Rao, Ramesh S, Raut A.N., Bhalerao V. B., Prajapati A., Khan I., Kumbhar G.C., Temkar V., Chaterjee S., Parikh G.P., Vawhal A, Sureshkumar S.]

2. An upgraded high dynamic range version of the common box electronics that comes after the front-end systems has been installed on the first 5 antennas. It has a much better dynamic range (1 dB compression and IP3 points) and is better in handling broadband signals without saturation, and also hosts the new monitor and control card that is part of the final system. [Temkar Vishal B., Kumbhar Ganesh C.]

3. As part of the attempt to keep improving the electronics for the upgraded GMRT, a new 3-stage Low Noise Amplifier (LNA) has been designed to provide a better design for the Band-5 (1000-1450 MHz) receiver of the GMRT. The prototype unit built has achieved a noise temperature of 20 degrees Kelvin, gain of 45 dB and input matching better than -10 dB over the entire band. It has been successfully installed on 2 antennas and is under detailed testing and characterisation before being taken up for mass production. [Raut A.N., Chatterjee, S.]

Highlights from the Signal Transport and Fiber-Optics Systems are as follows:

Having completed the main task of delivering a reliably working RF over fibre system to bring back the wideband signals of the upgraded GMRT from all of the 30 antennas to the central receiver building, more than a year ago, the team has turned its attention to other challenges. The prototype version of the ethernet optical fibre link that will allow control of the front-end electronics at the focus of the antenna, from the base of the antenna, was designed and tried out. This requires special RFI shielding of the equipment, and improvements in this are presently underway [Sureshkumar S., Raybole Pravin, Lokhande Satish, Rai Sanjeet]

Upgrades of the GMRT back-end systems

GMRT back-end systems

As part of the GMRT upgrade, new back-end systems are being implemented to achieve the specifications for the upgrade like increased bandwidth of 400 MHz, direct processing of RF signals, increased dynamic range, improved channel resolution in the digital back-ends etc. A significant feature of the new system is the reduction in electronics at the remote antenna sites and shifting of most of the complex signal processing operations to the Central Electronics Building (CEB) which will reduce the down time of antennas in case of problems. Some of the main developments in this year have been as follows.

1. Analog Back-end System

   The full Analog Backend system for all 30 antennas improved dynamic range, facility for variable gain, selectable signal bandwidth and individual LO signal for each antenna, has been completed and released for use, and is functioning well for more than 2 years now. Work on further improvements in the LO system was initiated during this year, which will provide a highly flexible configuration to provide independently settable LO signals for each polarisation of each antenna, alongwith the capability of phase memory when the LO frequency is switched back and forth between two different values. The prototype version of this new design was tested and will soon be entering mass production for all the 30 antennas. [Ajithkumar B., Shinde Navnath, Gupta Sweta, Nanaware D. K., Ganla Atul, Dhende Abhijeet, Phakatkar Sudhir, Hande P. J., Vishwakarma Ajay]

2. Digital Back-end Systems

   The full 30-antenna digital back-end system which implements a GPU-based hybrid correlator and beamformer (with incoherent and coherent modes
and a pulsar preprocessor) was completed more than a year ago. Further refinements that were carried out in the system during this year were: a real-time coherent dedispersion for the beamformer was completed and released; improvements in the spectral zoom mode were carried out; prototype set-up for buffering the user from the main system to preserve the real-time performance of the back-end, was completed and will be released shortly for regular use; improvements in the graphical user interface available to the operator were also carried out. Work was also initiated on the implementation of a parallel system which will get a copy of the digitised data from all the 30 antennas and will carry out specialised signal processing tasks that will enhance the performance capabilities of the GMRT. [S. Harshvardhan, Reddy, Sanjay Kudale, G. J. Shelton, Nilesh Raskar, I. M. Halagalli, I. S. Bhonde, B. Ajithkumar, Yashwant Gupta]

Work was continued on the scheme for the implementation of Walsh demodulation in the back-end receiver. The prototype had been tested last year and shown to achieve 99.5% rejection of unwanted leakage signals in the antenna signal path. Work was done this year to start the implementation of this scheme in the main system and make its performance more robust. [Sandeep C Choudhari, Navnath Shinde, Sweta Gupta, B Ajithkumar, Yashwant Gupta]

Further progress was made on the trials for a scheme for digitisation of signals at the antenna. This is a project being implemented in coordination with Optical Fiber group and involves digitising the RF signals at remote sites and transporting the digital data through OF cables to central station for combining and processing. More detailed studies were carried out using the prototypes which have been developed and installed at few antennas to study the performance of the system in comparison with the existing uGMRT receiver. [S. C. Choudhari, N. Shinde, Sweta Gupta, B Ajithkumar, Yashwant Gupta]

Radio Frequency Interference protection for the GMRT

One of the major challenges for the upgraded GMRT is to contain the problems posed by Radio Frequency Interference (RFI) from various sources of electromagnetic signals from man-made activities in and around the GMRT array. This includes identifying and mitigating the sources of RFI at their source, to finding techniques for avoiding or reducing the influence of RFI in the receiver chain, and finally to excising RFI at various stages of the receiver system. The activity spans work carried out by different groups at GMRT. Some of the main achievements during the last year are as follows:

RFI mitigation at source

The wideband operation of the upgraded GMRT significantly increases the risk of RFI from external and internal sources like commercial transmission (mobile, TV, FM radio), modern computers and network equipment and high voltage electrical lines. The RFI team continues to carry out extensive survey to identify sources of RFI and work out possible solutions. Some of the highlights for this last year as follows: a detailed characterisation of RFI from electrical transmission lines and equipment in the GMRT neighbourhood was carried out and items needing corrective attention were identified; work was done for designing and building RFI shielding enclosures for equipment at the observatory such as air-conditioning units, LED lamps, UPS units etc, and good success was achieved in many cases; detailed characterisation and follow-up of RFI from leakage of signals from cable TV systems in nearby towns was done. [P Raybole, S. Sureshkumar, Sanjeet Rai, Ankur Prajapati]

RFI excision in the back-end receiver

Different schemes for detection and filtering of RFI signals in the digital back-ends of the upgraded GMRT, based on statistical properties of the desired signal and RFI, are being developed. During this year, further tests and characterisation were carried out with the first version of the scheme that works in real-time on the digitised voltage signals from each antenna. Some improvements in this scheme, including moving to the integrated intensity domain, were also developed and are being tested. In addition, development of the filtering algorithm in the frequency domain was also initiated. Finally, further refinements were carried out to the filtering scheme that had been developed for the beamformer data, working in the time-frequency domain, and improved performance was demonstrated and made available to the user. [Kaushal D. Buch, Kishore Naik, Swapnil Nalawade, B. Ajithkumar, Aditya Chowdhury, Ruta Kale, Yashwant Gupta]
New Monitor & Control System for the upgraded GMRT

To control and coordinate the upgraded GMRT systems for performing astronomical observations, efforts are on to develop a next generation Monitor and Control (M&C) system. This includes modern hardware and software architectural features compared to the existing GMRT control system, including futuristic developments that could be of relevance to next generation radio telescopes such as the SKA. Some of the highlights are as follows. [Jitendra Kodilkar, Raj Uprade, Charudatta Kanade, Rahul Bhor, Mahadev Misal, C. Sateesh, B. Rajendran, Santaji Katore, Deepak Bhong, Sachin Sherkar, S. Nayak, Yashwant Gupta]

New M&C modules

New Monitor and Control Modules (MCM) developed based on Rabbit RCM 4300 micro-controller, completed mass production and had significant software and firmware developments to implement control of various GMRT sub-systems at antenna base and in the Central building. Installation and testing of these MCM cards was completed for the Sentinel, Optical Fiber and FPS sub-systems at antenna base. For simultaneously updating the firmware on multiple MCM cards over the Ethernet interface, a Remote Firmware Update application has been developed and tested. To update the firmware, a web-interface is provided. The application will be used to update/maintain the firmware running on rabbit MCMs for all 30 antennas.

Next Generation M&C Software System

NCRA is actively involved in the development of a next generation M&C system applicable for large systems (including radio telescopes like the GMRT and the SKA), in collaboration with the TRDDC research laboratory and partners from software industry. As a first step of this effort, a modern M&C system software is being developed for the GMRT, which can be used as a demonstrator for SKA and can help evaluate and test various kind of prototypes required in the SKA design. The development of Phase-2 of this system was completed, and Phase-3 is now well under way, wherein new features and capabilities are being added to the software, in addition to the basic capabilities that were implemented in Phase-1 and Phase-2. Also, the configuration is being expanded to cover more number of antennas. The design and growth are being in a manner that is in parallel with the existing M&C system. The software architecture of the new M&C system is based on the TANGO open source software framework, and supports features like data driven configuration, scalability, and facility to evolve. The software architecture of the new M&C system is thus more aligned with the requirements of the Telescope Manager functionality planned in SKA1, and is expected to have direct relevance and feedback into this SKA design work, that is led by India. The GMRT M&C system development work is being carried out by the GMRT Operations Group, in close collaboration with industry partners TCS Pune.

GMRT Servo system Upgrades

After completing all the major planned upgrades five months ahead of planned schedule, a new project to improve the operation of feed position systems (FPS) has been initiated. A new design of FPS was undertaken and tested in laboratory and on a mock feed turret. Last year, the main focus was antenna trials for validation of the design and repeatability tests with an aim to freeze the current design for mass production and commissioning. Following validation on C10 antenna, another system was installed on C04 antenna in January this year. Both these systems are being tested during regular operations. The current design is being improved based on field performance and it is planned to initially commission 5 more antennas next year. [S. Sabhapathy, S. Bagade, A. Kumar, B. Thiyyarat, T Haokip, S. Malu, A. Bhumkar and B. C. Joshi]

Release of the third phase of the upgraded GMRT

The progress achieved in the upgrade activities described above resulted in the third phase of the upgraded GMRT (uGMRT) being released to the user community. For the GMRT Observing Cycle 32, starting from April 2017, a 30 antenna uGMRT system supporting wideband observations of upto 400 MHz bandwidth with 2 bands fully functional (Band-5: 1000 to 1450 MHz and Band-3: 250-500 MHz) was released for users. For Cycle 33, which started in October 2017, 2 other bands of the uGMRT – Band-2: 120-240 MHz and Band-4: 550-850 MHz – were released for use for the first time, though with less than the full complement of 30 antennas. There has been a growing preference of users to start using the uGMRT systems over the legacy systems, with the ratio of proposals for the uGMRT overtaking those for the legacy system during this year.
Radio Physics Laboratory

Radio Physics laboratory (RPL) is a joint collaborative initiative between NCRA-TIFR and IUCAA. Its main goal is to provide a platform for training under-graduate students in science and engineering in radio astronomy techniques and instrumentation. Like the previous years, RPL organised Radio Astronomy Winter School for College students (RAWSC) from 18th to 26th of December 2017. Thirty college students (mostly in their second or third year of Graduation) selected from across India participated in this school.

A total of 10 lectures encompassing different topics of Astronomy & Astrophysics were arranged for them. They also carried out radio astronomy (e.g., radio emission from Sun, detection of HI from our Galaxy using the 3m RPL antenna) and laboratory experiments on physics and electronics (e.g., Noise temperature of resistors, Superheterodyne radio receiver). A visit to GMRT observatory was also arranged as part of this programme.

RPL facilities were also used for a two months project (May-June 2018) of an Integrated PhD student to study variation of line of sight velocity of Galactic HI at different Galactic longitudes.

Other than the above, RPL also demonstrated experiments to detect Sun and Galactic HI to about 30 Indian Academy of Science summer students on 5-6 July 2018.

GMRT Proposals and Time Allocation

GMRT observing Cycle 32 ran from 20 April 2017 to 27 September 2017 and Cycle 33 ran from 20 October 2017 to 26 March 2018, with the gap in between being the maintenance break, for upkeep and improvement activities. A total of 102 and 91 proposals were received, of which 73 and 70 proposals were allocated observing time in cycles 32 and 33, respectively. A total of 4667 hrs and 3777 hrs were requested and 1871 hrs and 1866 hrs were allocated for these two observing cycles, giving an over subscription rate of 2.5 and 2.0, respectively. In cycle 32, the usage of frequency bands was: Band-5 / 21 cm -- 45%, Band-4 / 50 cm -- 18%, Band-3 / 90 cm -- 34% and Band-2 / 200 cm -- 3%. For cycle 33, the corresponding numbers were somewhat similar: Band-5 / 21 cm -- 41%, Band-4 / 50 cm -- 23%, Band-3 / 90 cm -- 35% and Band-2 / 200 cm -- 1%.
Members

Pune

Research Scholars

Post-Doctoral Fellows

Scientific
Technical

Administration

Auxiliary

Khodad
Scientific

Technical

Administration

Auxiliary

Ooty
Krishnakumar M. A., Manoharan P. K., Prabhu D. S., Subramanian Prasanna, Surnis Mayuresh Prakash
National and International Involvement

Bhattacharyya, Bhawiti
1. Member, Marie Curie Alumni Association, since 2015
2. Member, Square Kilometre Array (SKA) pulsar science working group, since 2015

Chengalur, Jayaram
1. Member, National Committee of the IAU
2. Member, SKA Science Working Group
3. Member, Editorial board, Journal of Astronomy and Astrophysics
4. Member, Sectional Committee, Indian Academy of Science
5. Member, Chair Scientific Organizing Committee, Astronomical Society of India

Gupta, Yashwant
1. Science Director from India, Board of the international Square Kilometre Array Organisation
2. Leader of the Telescope Manager Consortium -- an international collaboration for work on the design of the Telescope Manager system for the SKA, led by NCRA
3. Chair, TMT-India Software Work Packages Monitoring Committee that oversees the overall development of software packages in India, for the Thirty Metre Telescope International Project
4. Chair, Astronomy and Computational Physics sub-group of the Applications Group of the National Supercomputing Mission
5. Member, Governing Council of the Indian Institute of Astrophysics (IIA), Bengaluru
6. Member, BRICS Astronomy Working Group

Joshi, Bhal Chandra
1. Member, Panel on Education, COSPAR
2. Member, RadioAstron International Science Committee
3. Member, GMRT Time Allocation Committee

Kharb, Preeti
1. Scientific Organising Committee, International conference on Revisiting narrow-line Seyfert 1 galaxies and their place in the Universe, Italy, 9-13 April 2018
2. Reviewer, NASA’s Chandra X-ray Observatory Cycle 19 Peer Review Panel, June 20-21, 2017
3. Reviewer, Grant proposal for the National Science Centre, Narodowe Centrum Nauki, NCN, panel ST9, Govt. of Poland

Lal, Dharan Vir
1. Core Member SKA: Extragalactic Continuum (galaxies/AGN, galaxy clusters)
2. Co-chair Member, SKA-India: Continuum Survey

Manoharan, P.K.
1. Editor, Geosciences Letters, Asia Oceania Geosciences Society (AOGS)
2. Editor, Journal of Space Weather and Space Climate
3. Editor, Indian Journal of Radio Science
4. Editor, National Coordinator, International Space Weather Initiatives (ISWI) Programme in India
5. Member, Axford Medal Nomination Committee, Asia Oceania Geosciences Society (AOGS)
6. Member, Astronomical Society of India (ASI)
7. Member, Asia Oceania Geosciences Society (AOGS)
8. Member, International Astronomical Union (IAU)
9. Member, Community of European Solar Radio Astronomers (CESRA)
10. Member, Scientific Organizing Committee of the IAU Symposium IAUS 340, Long-Term Datasets for the
Understanding of Solar and Stellar Magnetic Cycles, February 19-24, 2018
11. Co-PI, Aditya-L1 Space Solar Coronagraph Project, ISRO, India

Oberoi, Dirya
1. Co-chair, Solar, Heliospheric and Ionospheric Science

Visits

Bhandari, Hanumanth Rao
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Bhattacharyya, Bhaswati
1. New York University, Abu Dhabi, March 2017
2. Jodrell Bank, Manchester, UK, September 4-8, 2017
3. University of Manchester, Manchester UK, September 11-15, 2017
4. Bologna, Italy, 19-23 June 2017

Chaudhri, S.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Choudhury A.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Gupta, Yashwant
1. Rotterdam, The Netherlands, June 12-17, 2017
2. 32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017
3. IIA, Bangalore, September 24-25, 2017
4. Bonn, Germany, and Bologna, Italy, Nov. 7-9, 2017
5. Sydney, Australia, December 12-15, 2017
6. BITS Hyderabad, January 6-8, 2018
7. ASI Hyderabad, India, February 5-9, 2018
8. Kolkata, India, March 6, 2018
9. Manchester, UK, March 7-9, 2018

Jay, Bhal Chandra
1. TIFR, Mumbai, April 28, 2017
2. IUCAA, Pune, May 15-16, 2017
3. IIT, Guwahati, May 18-20, 2017
4. Jodrell Bank Observatory, Lower Withington, Macclesfield, Cheshire, UK, September 4 - 8, 2017
5. BITS-Pilani, Hyderabad, Hyderabad, January 3-8, 2018
6. Osmania University, Hyderabad, February 5 - 9, 2018
7. Saha Institute of Nuclear Physics, Kolkata, March 6-9, 2018

Kale, Rata
1. Physics of the ICM, Beijing, China, April 3-7, 2017
2. University of Montreal, Montreal, Canada, August 17-28, 2017
3. Raman Research Institute, Bangalore, October 1-7, 2017
4. ASI Meeting, Hyderabad, February 5-9, 2018

International Science Working Group of the Square Kilometre Project.
2. Vice-Chair, Solar, Heliospheric and Ionospheric Science consortium of the Murchison Widefield Array project
3. Member, Executive Council, Astronomical Society of India

5. Salt Lake City, USA, March 18-28, 2018

Kanskar, Nissim
1. Columbia University, New York, USA, April 2018
2. National Radio Astronomy Observatory, Socorro, New Mexico, USA, April 2018
3. University of California, Santa Cruz, USA, March 2018
4. Ashoka University, Haryana, March 2018
5. NISER, Bhubaneswar, March 2018
6. Presidency University, Kolkata, October 2017
7. University of California, Santa Cruz, USA, July 2017
8. Physical Research Laboratory, Ahmedabad, June 2017

Kator, S.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Kharab, Preeti
1. Centre for Astrophysics (CfA), Cambridge MA, USA, 22-27 June 2017
2. The Netherlands Institute for Radio Astronomy, ASTRON, March 24 - April 9, 2018

Manoharan, P.K.
1. Harvard-Smithsonian Center for Astrophysics, Harvard University, Cambridge MA, USA, August 7, 2017
2. MIT Haystack Observatory, USA, August 8, 2017
3. Space Weather Laboratory, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA, October 1-30, 2017

Nayak, S.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Oberoi, Dirya
MIT Haystack Observatory, 27 July - 1 August, 2017

Raut, Anil
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Raybuck, P.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017

Reddy, Harshvardhan S.
32nd General Assembly of URSI, Montreal, Canada, August 19-26, 2017
Invited Talks

Bhattacharyya, Bharati
1. Broad Impact of Low-frequency radio astronomy, Pulsars and transients with the GMRT. INAF - Istituto di Radioastronomia, Via Gobetti, Bologna (Italy), June 19–22, 2017
2. Searching for pulsars with the GMRT. Science with a UAE DSN antenna, New York University Abu Dhabi, March 25, 2018

Chandra, Poonam
1. Exploring core-collapse supernovae at radio frequency. Oskar Klein Centre Colloquium, Stockholm University, Jan 31, 2018
2. RETCO-III, IIST Thiruvananthapuram, 4-6 June 2017
3. Panelist on Multi-messenger Astronomy with GWs in LIGO-India: The road ahead, IUCAA, 15-16 May 2017

Chengalur, Jayaram
Radio Astronomy and the GMRT, Young Astronomers Meet, IUCAA, May 26, 2017

Gupta, Y.
1. The Upgraded GMRT: Current Status and Future Plans. Workshop on Gamma-ray Bursts: Prompt to Afterglow, GMRT, Khodad, July 6, 2017
3. Radio Astronomy at NCRA, BRICS Astronomy Workshop on Infrastructure and Instrumentation Pune, September 22, 2017
5. The uGMRT: Opening new windows to the Low frequency radio Universe. Science at Low Frequencies IV, Sydney, Australia, December 13, 2017
6. Pulsars with the Next Generation Multi-element Telescopes: from the GMRT, to the SKA. Neutron Star Symposium, BITS Hyderabad, January 7, 2018
7. The upgraded GMRT: Overview and Prospects for Pulsar Science. Annual meeting of the Astronomical Society of India Hyderabad, February 8, 2018
8. Astrophysics at Low Radio Frequencies: from the uGMRT to the SKA. AAPCOS-2018, Kolkata, March 6, 2018
9. Computational Astrophysics: Challenges and Opportunities. ThoughtWorks Symposium, Pune, March 24, 2018

Joshi, Bhal Chandra
1. Looking for Gravitational Waves with a radio pulsar observatory - Indian Pulsar Timing Array experiment and TATA Pulsar Timing Array. ASET Colloquium, TIFR, Mumbai, April 28, 2017
2. Panel Discussion on Characterizing GW sources. LIGO-India: The Road Ahead, IUCAA, Pune, May 16, 2017
3. Looking for Gravitational Waves with a radio pulsar observatory. 29th meeting of the Indian Association for General Relativity and Gravitation (IAGRG) - The Era of Gravitational Waves, IIT, Guwahati, May 19, 2017
4. Introduction to radio pulsars/neutron stars. Pulsar Astronomy with uGMRT Boot-Camp, BITS-Pilani, Hyderabad Campus, Hyderabad, January 3 and 4, 2018
5. Pulsar timing technique and its applications to neutron star astronomy. Pulsar Astronomy with uGMRT Boot-Camp, BITS-Pilani, Hyderabad, January 3 and 4, 2018
6. Simultaneous multi-frequency wide-band observations of Four musketeers with legacy and upgraded GMRT. Multi-Wavelength Neutron Star Workshop, BITS-Pilani, Hyderabad, January 7, 2018
7. Multi-epoch multi-frequency monitoring of pulsars with ORT and GMRT. NCRA Academic day, NCRA-TIFR, Pune, January 18, 2018
8. Precision pulsar timing with the ORT and the GMRT and its applications in pulsar astrophysics. Advances in Astroparticle Physics and Cosmology 2018, Saha Institute of Nuclear Physics, Kolkata, March 7, 2018

Kale, Ruta
2. Understanding the intra-cluster medium through radio surveys of galaxy clusters. Colloquium, University of Montreal, Montreal, Canada, August 28, 2017
3. Clusters of galaxies with the Upgraded GMRT. Plenary talk at the 36th Annual Meeting of the Astronomical Society of India, Osmania University, Hyderabad, February 5 – 9, 2018
4. The Upgraded GMRT: Opening new windows to the radio Universe. Conference Snowcluster 2018-The Physics of Galaxy Clusters, Salt Lake City, Utah, USA, March 18 – 23, 2018

Kanekar, Nissim
1. Cold Gas at High Redshifts. East Asia ALMA Meeting, Daejeon, South Korea, November 2017
2. The gas mass and star formation rate of star-forming galaxies at $z>1$. TMT Science Forum 2017, Mysuru, September 2017
3. The Gas Mass and Star Formation Rate of Star-forming Galaxies at $z\sim1.3$. The Plasma Universe and its Structure Formation workshop, IUCAA, Pune, August 2017
Kharab, Preeti

1. A Low Frequency Study of Seyfert Galaxies. Quasar Tea seminar, CfA, Cambridge USA, June 2017
2. Probing the Origin of Radio Outflows in Seyferts and LINERs (Contributed). When Brandeis met Jansky: astrophysics and beyond, Brandeis University, Waltham MA USA, June 28-30, 2017
3. A Parsec-scale Look at the Central Regions of Low Luminosity AGN. AstroSat View of AGN Central Engines, IUCAA, Pune, December 18-21, 2017
4. Radio View on AGN. Franco-Indian Astronomy School, From Re-ionization to Large Scale Structure: A Multiwavelength Approach, IUCAA, Pune, February 11-17, 2018
5. A Multi-scale Study of Outflows from Low Luminosity AGN, Energetics and Life-Cycles of Radio Sources, ASTRON, the Netherlands, March 26-28, 2018

Lal, Dharam Vir

1. GMRT upgrade: Current status and early science results. SKA Office, SKA South Africa, April 13, 2017
2. A high resolution, high sensitivity, low radio frequency view of diffuse, low-surface brightness targets using upgraded GMRT. Istituto di Radioastronomia, INAF, Bologna, Italia, June 12, 2017
3. The uGMRT summary. SPARCS VII: The Precursors Awaken, July 17-21, 2017

Manoharan, P.K.

2. Space Weather activities in India. UN/US International Space Weather Initiative Workshop, Boston College, Chestnut Hill, MA, USA, August 3, 2017
4. Studies of 3-D Solar Wind with the Ooty Radio Telescope. MIT Haystack Observatory, USA, August 8, 2017
5. Propagation of coronal mass ejections. Space Weather Laboratory, NASA Goddard Space Flight Center, Greenbelt, USA, October 17, 2017
6. Importance of solar wind turbulence index in understanding space weather events. Four-in-One Workshop on Tackling Outstanding Problems in Heliophysics and Space Weather, Clayton Hotel, Cardiff, Wales, UK, December 3, 2017

Oberoi, Divya

1. SHI Science Update. MWA Project Meeting, Bologna, Italy, June 16-17, 2017

Conferences Organised by the Centre

Radio Astronomy School (RAS)
NCRA, Pune, 28 August to 8 September, 2017 (Organiser: Preeti Kharb)

Chandra/CIAO workshop
October 23-27, 2017 (Organiser: Dharam Vir Lal)

Astrophysical Jets 2018
February 5, 2018 (Organisers: Dharam Vir Lal and Preeti Kharb)

Non-DAE Research Projects

Y Gupta

Bhal Chandra Joshi (Co-PI: P.K. Manoharan)
Pulsar Monitoring Observations Program with the Upgraded Ooty Radio Telescope (Fundedy Science and Engineering Research Board, Department of Science and Technology)

Ruta Kale
Unveiling non-thermal footprints of cluster assembly in the Universe (DST-INSPIRE: Faculty Award Project, Department of Science and Technology), 28 April 2015 – 27 April 2020
How do proteins fold, unfold and misfold?

The laboratory focuses on two aspects of protein folding: how cooperative are the reactions, and how folding begins. Using hydrogen exchange-mass spectrometry, the laboratory has demonstrated how denaturant can sculpt the free energy landscape of protein folding to promote cooperativity. Using microsecond mixing methods in conjunction with protein engineering, it has shown how non-native interactions can play a productive role in protein folding and unfolding. The laboratory has also studied the mechanism of misfolding of the prion protein which leads to neurodegenerative disease. Using a mutational approach, hydrogen exchange mass spectrometry, as well as real time NMR, the laboratory has identified several of the key intra-molecular interactions that must be perturbed before misfolding can occur. The laboratory has also delineated the mechanism by which protective mutations prevent infection of an animal by infectious prion strains. [Jayant B. Udgaonkar, Sandhya Bhatia, Harish Kumar, Prashantkumar Navalbhai Jethva, Neha Nandwani and Sreemantee Sen]

Mechanics and Electrical Activity in the Heart

Mechanical Forces influence the Electrical System in the Heart. Fluid movement within the heart generates substantial shear forces, but the effect of this mechanical stress on the electrical activity of the human heart has not previously been examined. We have exposed hERG1a channel–expressing HEK293T cells to laminar shear stress and observed that this mechanical stress increased the whole-cell current by 30–40%. Detailed electrophysiological analyses have identified the state transitions responsible for this shift. Using specific inhibitors of focal adhesion kinase, a regulator of mechano-transduction, we also found that the shear-induced modulation of the whole-cell current depended on the integrin pathway. Mutagenesis approaches have been used to implicate a domain in the N-terminus of the protein in sensing mechanical shear stress. We conclude that a mechano-electric feedback pathway modulates hERG channel activity through the integrin pathway, indicating that mechanical forces in the heart influence its electrical activity. [M. K. Mathew, Samrat N. A. Roy]

Genomics of bacterial adaptation

The model bacterium E. coli can survive and divide independent of the origin of replication (oriC) under certain conditions, including those in which RNA-DNA hybrids which can prime DNA replication are stabilised (cSDR for constitutive stable DNA replication). Are there discrete sites (oriK) from which such non-canonical replication initiation occur? Or are such sites distributed across the chromosome, consistent with the genome-wide prevalence of RNA-DNA hybrids in these strains? How does E. coli, whose genome organisation has evolved to maximise the outcomes of replication initiation from oriC adapt to cSDR?

Using suppressor mutant isolation from laboratory evolution experiments and next-generation genomics, we demonstrate the preferential initiation of replication from a particular locus (oriK45) in cSDR strains. Initiation from this site will invert the direction of DNA replication around oriC, thus resulting in detrimental clashes between the replicative DNA polymerase and RNA polymerase transcribing tRNA operons. Therefore, the most prominent suppressor of the growth defect of cSDR strains is an inversion of the relevant cluster of tRNA operons. These inversions are found in other E. coli strains, which we predict will be tolerant to mutations that activate cSDR. [Aswin Sai Narain Seshasayee, Reshma T. V., Harshavardan, Akshara Dubey, Terence Christie and Nitish Malhotra]
The Ubiquitin-Proteasome pathway and its role in Proteostasis

The research undertaken by our lab included questions around (i) how proteins are folded/misfolded, (ii) how the misfolded, toxic proteins are degraded by the Ubiquitin-Proteasome pathway, and (iii) can protein-folding principles be used to design ordered structure to serve as sensors or enzyme-clusters. Last year, we had looked at the misfolding of Prion induced by physiological salt concentrations at acidic pH, and inferred that salt screens charges around Prion, and breaks a critical salt-bridge in the protein to initiate oligomerization. A major process of degradation of the misfolded proteins like Prions, is the ER-associated degradation (ERAD). We investigated the dynamics in the obligate ERAD pathway proteins Ube2g2 and gp78. It was discovered that gp78 modulates the dynamics in Ube2g2 at each step of the reaction path, to ensure highly efficient ubiquitination machinery. In a separate project, we discovered that the NSAID drugs like indomethacin significantly modulate the functionality of 26S proteasome. The design of domain-swapped proteins by altering the beta-turns of a protein was investigated, and new rules for designing clean swapped dimers by truncating beta-turns in proteins were uncovered. The Small Ubiquitin-like Modifier homolog SMO1 plays an immense role during the embryonic development of C.elegans. Our lab revealed the structure of SMO1, its dynamics, the mechanism of SMO1 modification on substrates, and, the mechanism behind the identification of SMO1 modified proteins by receptors. [Ranabir Das, Parag Surana, Suhas Bhate, Kiran Chatterjee, Purushotham Reddy, Vasvi Tripathi, Batul Habibullah, Hitendra Negi, Priyesh Mohanty and Rashmi J.]

Structure to signaling: Insights into bacterial biology through RNA structures

The lab’s program is evolving around two main themes - understanding how RNA structures influence cellular processes like transcription and translation and identifying new classes of regulatory RNAs using a structure-centric approach, to ultimately uncover their functions and mechanisms. Using a combination of biochemical, structural and biophysical approaches we aim to understand how RNAs create the chemical complexity required to sense diverse small molecules and proteins; how naturally occurring signal sensing RNAs function and in the long term-how these interactions can be exploited to develop RNA-based tools for sensing small molecules and proteins in the cell. One of our currently efforts is towards identifying small RNAs that are specifically induced under infection-like conditions, in pathogenic mycobacteria. We find a coordinated transcriptional and post-transcriptional program that integrates cellular ironlevels to lipid catabolism; explaining how mycobacteria might initiate lipid breakdown upon sensing host signals. Another area of interest in the lab is to identify the RNA mediated regulatory program that governs iron-homeostasis across bacteria. To this end we have discovered two RNA families that are widespread across bacterial species. We are currently investigating how these RNAs might function in the cell and what cellular pathways they control. [Arati Ramesh, Anjali K, Dolly Chetan Mehta, Anirudh KN, Siladiitya Bandyopahaya, Susmitnarayan Chowdhury]

DNA damage: response and repair pathway

The lab is broadly interested in understanding the regulation of DNA damage response and repair in microbial systems in vivo. We employ a live-cell imaging based approach in combination with genetic and molecular biology tools. While we primarily use bacterial systems to address these questions, our recent work has led us to look at asymmetric partitioning of damaged DNA in the context of bacteria as well as mitochondria.

1. Damage response and cell cycle regulation: Regulation of recovery from DNA damage-induced stress in bacteria

The aim of this project is to understand how bacterial cells subject to a pulse of DNA damage restore chromosome replication, segregation and cell division.

2. Repair pathway choice: Replication stability at DNA lesions and regulation of error-prone polymerase activity

The aim of this project is to understand the mechanism of action and regulation of the translesional (TLS) repair pathway in Caulobacter and its impact on replisome stability and fork progression across DNA lesions.

3. Repair pathway regulation: how are DNA double-strand break (DSB) ends organized during homology search

We aim to elucidate the organization of processed DSB ends to understand how movement of the ends is coordinated for successful homology search and whether RecN plays a role in facilitating the same. [Anjana Badrinarayan, Nitish Dua, Afroze
Membrane protein structure and dynamics

Our research focused on protein structure and dynamics with particular emphasis on membrane proteins coupled with electron microscopy. Some of the projects that have been completed and initiate are described below.

1. PaaZ is a bi-functional enzyme, which is involved in degradation of aromatic ring containing compounds that are common environmental pollutants. We determined multiple structures of PaaZ with substrate bound and provide an explanation on the substrate transfer mechanism. The manuscript describing the results is currently under revision in Nature Communications. This work was done by Nitish Satyanarayan in Prof. Ramasamy’s group (InStem) and Giuseppe Cannone (MRC-LMB, Cambridge).

2. Dimethylformamidase isolated from bacteria identified in industrial wastes hydrolyses dimethyl formamide, which otherwise is a pollutant. Using cryoEM, we identified that the enzyme exists in two oligomeric state (dimer and tetramer) and this equilibrium is dependent on salt and obtained maps to 3.2 Å. Several interesting features have emerged from the structure including the presence of new fold and a novel Iron binding site. This work was done with Chetan Arya in Prof. Ramasamy’s lab, InStem.

3. Mechanism of translational regulation by tsRNA (Lahari Yeramala)


Neurobiology

Computational and Experimental approaches to Memory and Plasticity

The laboratory works on sequential activity in the brain, and how it is recognized and generated. Speech, music, dance, and thought all involve sequential activity of ensembles of neurons, and the capability hierarchical composition of sequences can give rise to higher-order processing such as abstraction. We have performed simulations to show that sequence recognition on timescales relevant to sensory perception, speech and thought may be performed by reaction-diffusion signaling in small regions of brain cells, such that thousands of such pattern recognitions can happen in parallel in each cell (Bhalla, 2017). We have developed numerical methods for carrying out such simulations (Brocke et al 2017, Vooturi et al 2017). In other work we have reported how excitatory and inhibitory inputs are closely balanced in neuronal computation (Bhatia et al 2017). [Upinder S. Bhalla, Sahil Moza, Soumya Bhattacharjee, DILawar Singh, Aditya Asopa, Bhanu Priya S, Aanchal J. Bhatia, Kambadur Ananthamurthy, Sathya Subramaniam, Ekaterina Brocke, Anu Nair, G.V. Harsha Rani, Nisha Viswaan]

Synaptic plasticity in the amygdala: implications for stress-related psychiatric disorders

Dr. Chattarji's research has demonstrated how stress leaves its mark in the amygdala by generating new synapses with greater capacity for plasticity, thereby creating an ideal neuronal substrate for affective disorders. Importantly, these findings also highlighted for the first time the unique features of stress-induced plasticity in the amygdala that are strikingly different from the stress-induced impairment of structure and function in the hippocampus and cortex. Findings from his laboratory represent noteworthy breakthroughs that also carry significant clinical implications for stress-related psychiatric disorders. [Sumantra Chattarji, Rohit Dey, Saptarnab Naskar, Prabahan Chakraborty, Giselle M Fernandez, Jesvin Singh Madan, Kanika Gupta, Furquan Aboobakar Khizar, Rohini Subramaniam, Ashutosh Shukla, Bhaktee Donganik]

Intracellular calcium signaling in neurons

Cellular events are often mediated by spikes of cytoplasmic calcium, which either enter the cell from the external milieu or are released from internal stores. Dr. Gaiti Hasan’s lab studies intracellular Ca2+ release followed by replenishment of internal stores through store-operated Ca2+ entry (SOCE) and the effect these changes in cellular calcium have on neuronal and systemic physiology. Some of their findings in the last one year are: 1) Store-operated Calcium entry and gene regulation: The group has demonstrated that reduced
SOCE in neurons changes gene expression profiles with the majority of genes being downregulated. This finding is significant in the context of identifying gene expression as a mechanism that drives neurodegeneration in neurons with dysregulated intracellular calcium signaling, such as Purkinje neurons in Spinocerebellar Ataxia 15/16/29 (Shlesha Rajesh Richhariya and Siddharth Jayakumar); 2) Store-operated entry and development of the central nervous system: By generating targeted mutants in the gene encoding STIM in Drosophila, they have shown that STIM function is required in dopaminergic neurons for normal larval growth. [Gaiti Hasan, Shlesha Rajesh Richhariya, Siddharth Jayakumar and Trayambak Pathak]

**Neural Circuits and Development Lab**

The group’s research interests are in understanding the control and co-ordination of locomotion by motor centers in the brain. Among the many motor centers of the CNS, the cerebellum is one of the most primitive structures and is present in all jawed vertebrates. The lab seeks to understand how circuits in the cerebellum control adaptive locomotion. Specifically, the focus is on understanding the role of Purkinje neurons in sculpting cerebellar output and motor behavior. The lab uses zebrafish (Danio rerio), a teleost that is native to India as the model organism.

Using genetic tools Purkinje neurons were labelled and targeted for whole cell patch clamp recording and calcium imaging. It was demonstrated that these neurons exhibit membrane potential bistability and that they represent motor bouts in two modes, either in terms of calcium spikes or by sodium spikes depending upon their membrane potential. It was also shown that Purkinje neurons are modulated by dopamine and express a cytosolic phosphoprotein responsive to dopamine at very high levels. The current efforts of the group are directed at understanding the role of this phosphoprotein in regulating dopaminergic neuromodulation in Purkinje neurons. [Vatsala Thirumalai, Mohini Sengupta, Lena Mareike Josefine Robra, Sriram Narayanan, Shaista Jabeen, Urvashi Jha, Vandana Agarwal, Sahana Sitaraman, Aalok Varma, Igor Kondrychyn and Gnaneshwar V. Yadav]

**Behavioral and molecular mechanism of honey bee behaviour under natural conditions**

Research in the honey bee lab focuses on two major research areas: (a) Molecular processes involved in complex behaviors, and (b) diversity and evolution of behaviour among honey bees. In the last year, we made major progress was made in the following two research projects:

1. **Molecular mechanisms involved in daily foraging**
   
   Time-restricted feeder presentation in an outdoor flight enclosure leads to an entrainment of the honey colonies foraging activity. We were able to show that feeder entrainment at different times of the day (morning vs evening) lead to changes in the cycling of clock gene expression. Active foraging itself induced an upregulation of the immediate early gene Egr-1 (Early growth response protein) and also upregulation of selected Egr-1 downstream genes. Time-training over several days resulted in an upregulation of Egr-1 even under the condition of inhibited flight behaviour. Our results are a first step in identifying molecular processes involved in time-space memory in insects. [Axel Brockmann, Roshan Fatima Begun, Sruthi Unnikrishnan, Divya Ramesh, Ebi A. George, Hemalatha Baghavan, Rikesh Jain, Aridni Shah, Arumoy Chatterjee, Prabhu M.V. and Manal Shakeel]

2. **Updating of dance information in individual honey bee foragers:**

   Analysis of dance behaviour (i.e. waggle run duration) of individual foragers before and after shifting feeder distance showed that most foragers need several visits to the new location to generate a new waggle run duration. Experiments in which we shifted the feeder twice indicated that generating waggle run duration involves two different memories, a short term “working memory” and a long term memory. These finding will help to investigate the molecular processes involved in dance behaviour. [Axel Brockmann, Roshan Fatima Begun, Sruthi Unnikrishnan, Divya Ramesh, Ebi A. George, Hemalatha Baghavan, Rikesh Jain, Aridni Shah, Arumoy Chatterjee, Prabhu M.V. and Manal Shakeel]

**Molecular regulation of cellular functions in the adult brain**

Our lab seeks to understand specific molecular actions that underlie cell-specific processes and inter-cellular interactions influencing normal functionality of the brain. Broadly, we are interested in adult neurogenesis, mature neuronal maintenance, and microglial regulations in the adult brain.

We have identified a gene that is critically important for
adult neurogenesis, a process by which new neurons are continually generated in the adult brain in specific locations. In the last year we have uncovered the cellular events underlying the proper execution of this process. Our data demonstrated that the deletion of our gene-of-interest, specifically in the neural stem cells, leads to precocious development of neurons, ultimately leading to exhaustion of the stem cell pool and reduction of adult neurogenesis.

In another project, we are investigating the molecular mechanisms underlying longevity of neurons; one of the most long-living cell type of our body, with little, if any, capacity for regeneration. In the last year, we have discovered a factor that is critical for the maintenance of mature neurons in the adult brain. Our data demonstrated depletion of mature neurons in response to inducible deletion of this factor specifically in projection neurons in adult murine brain. [Hiyaa Ghosh, Rajit, Swathi, Tarana, Shariq and Dipannita Sarkar]

**Cellular Organization and Signalling**

**Nucleating a biomedical and viral diseases ecosystem**

Dr. Sudhir Krishna’s lab focuses on understanding the progression of human cervical cancers, a major malignancy in India. The group has recently characterized a sub-set of CD66+ cells that drive these tumors with distinctive properties in terms of migration, metastasis, self-renewal etc. The other major effort in recent times has been to the creation of an enabling environment for younger investigators to develop strong research themes in virology with a focus on flaviviruses. Using NGS the group has characterized a number of viral outbreaks across the country. This work feeds into vaccine design, viral epidemiology etc. [Calvin Steve Rodrigues, Aswathy A. K., Leanna Rose Joy, Krithika Badarinath, Deepak Arya, Lokendra Yadav, P. Annapurna, Sasikala P. Sachithanandan, P. Chitra, Amul Nisheetha P. J., Deepali Krishnan, Anshika Singh]

**Mechanisms of membrane organization and endocytosis**

The primary focus of our laboratory is to understand physico-chemical principles behind the organization of the plasma membrane in a living cell and how this informs cell and organismal physiology. Specifically we wish to understand how a eukaryotic cell constructs signalling complexes at the plasma membrane and regulates endocytic processes. The local and global control of membrane composition is also an emerging question in the laboratory.

The plasma membrane does not merely separate the outside from the inside of a cell but mediates bilateral communication. To understand how eukaryotic cells respond and react to their environment, we study how a cell can regulate the local organization of its membrane constituents, while the membrane itself behaves like a fluid matrix. New insights from a variety of studies, including that from our laboratory, show that the local chemistry of these 2D plasma membranes is finely tuned and far from an equilibrium mixture. We are providing a new framework wherein the cell membrane behaves as an active composite, with the underlying dynamic cortical actin filaments controlling the local composition of membranes. There are numerous offshoots from such an understanding of membrane organization. Among them, we now seek to explain how cells can construct signalling complexes and sort membrane constituents, in response to their environment. The cell membrane also is the site for the assembling endocytic machinery, in response to a number of extrinsic and intrinsic cues. To broaden our understanding of membrane homeostasis, we also study endocytic mechanism, in particular a class of non-canonical endocytic pathway that functions in the absence of both clathrin and dynamin, and how this regulates the developmental program in the context of a developing wing imaginal disc of Drosophila. [Satyajeet Mayor, Abrar Ahmed Bhat, Chaitra Prabhakara, Chandrima Patra, Mugdha Shrikant Sathe, Parijat Sil, Rashmi Kiran Godbole, Sankarshan Talluri and Joseph Jose Thottachery]

**Lipid Signalling in Cell Biology and Human Disease**

Our long-term scientific interest is to understand cellular communication mediated by lipid molecules generated by the metabolism of phosphatidylinositol. Phosphoinositide signals provide molecular control for key sub-cellular processes such as membrane remodelling, cytoskeletal function, transcription and
translation. Through these processes, this signalling pathway orchestrates basic cellular behaviours such as cell division, shape changes, polarized movement and cell death and this plays a key role in a number of physiological processes including early embryogenesis, lymphocyte development and function as well as neuronal activity. The overall goal of our work is to understand how the architecture this signalling cascade is designed to optimally deliver physiological outputs. The work is multidisciplinary and done using a combination of Drosophila and human disease models. Over the last year we have uncovered the function of key enzymes that regulate lipid signalling and provided a molecular mechanism by which they control cellular processes. These include the mechanism by which lipid molecules are exchanged between cellular compartments, the control of membrane turnover and receptor activity by lipids and a quantitative model of the turnover of lipids during critical cell signalling reaction important for brain function. We have also initiated a study of equivalent processes in human disease states using modern stem cell technology. [Raghu Padinjat, Rohit Suratekar, Kamalesh Kumari, Shweta Yadav, Rajan Thakur, Sudipta Ashe and Deepti Trivedi]

Theoretical approaches in cell biology: physics of active, evolving systems

We are interested in how living systems, composed of physical entities such as molecules, cellular aggregates and driven far-from equilibrium, have self-organized (evolved) to perform ‘engineering tasks’ such as efficient processing of information, computation and control. This potentially brings together many fields of research including non-equilibrium statistical physics, soft active mechanics, information theory and control theory to the study of biology.

We explore new physical and chemical principles underlying biological organization across scales, from functional biomolecules, to subcellular organelles, to the cellular and tissue scale. We are interested in the folding and packaging principles that govern the three dimensional functional organization of large biomolecular assemblies, such as proteins and chromatin, and their interactions with other cellular components. At a larger scale, at the subcellular, cellular and tissue level, organization is often driven by active mechanisms fuelled by energy.

Typically these active forces arise from (i) the coupled dynamics of the cytoskeleton, motors and cytoskeletal regulatory proteins, and (ii) the active dynamics of fission and fusion of organelles, and regulate the flux of mass, stress, energy and information. Using the framework of active hydrodynamics, we study the mechanical response, pattern formation, symmetry breaking, hydrodynamic instabilities and information flows in both in vivo and in vitro reconstituted active systems. [Madan Rao, Krishnan S. Iyer, Abhishek M. and Saptarshi Dasgupta]

Modulation of host cellular pathways by intracellular pathogens

Dr. Varadharajan Sundaramurthy’s lab works on host-pathogen interactions, specifically on how fundamental host cellular pathways such as endocytosis and autophagy are modulated by intracellular infections. The lab focus is on two distinct pathogens, M. tuberculosis that causes tuberculosis and the liver stage of Plasmodium spp, that cause malaria. The aim is to combine quantitative image analysis with conventional tools of cell and molecular biology to explore the relationships between the two pathogens with the host systems at molecular, cellular and tissue levels. Their recent results show that both pathogens cause global alterations in the organization and dynamics of the host cell endocytic network. These alterations include subcellular redistribution of specific endosomal pools and an increase in the number and content of distinct endosomal populations specifically in the infected cells. In some cases, abrogation of these alterations by chemical treatment results in killing of the pathogen, suggesting the importance of these changes in pathogenesis mechanisms. The results therefore suggest that intracellular pathogens cause extensive re-wiring of the host endocytosis machinery and exploit its plasticity for their benefit. These results provide further support for host directed therapeutics against infectious diseases. [Varadharajan Sundaramurthy, Kuldeep Sachdeva, Manisha Goel, Pallavi Mathur, Parakh Mody, Shadab Nizam, Piyush Baindra and Lakshmi Balasubramanian]

Hierarchical network in super-enhancers transcriptionally regulates INK4/ARF locus

Often gene regulation is governed by distal-regulatory elements such as enhancers that regulate the target gene transcription by delivering important protein cargos to the promoter. While the biological importance of enhancers has been long appreciated, a mechanistic
understanding of how distinct cohorts of enhancers up-regulate some genes while simultaneously down-regulate other coding target genes remain unsolved for example, within recently identified clusters of enhancers known as super-enhancers. Using disease relevant INK4/ARF locus, we discovered that locus is positively regulated by super-enhancer located 200 kb downstream in HPV-positive cervical cancer cells. Only three enhancers ECAD6, 9 and 13 out of 33 physically loop with the INK4A promoter. Surprisingly, inhibition of eRNAs on these three enhancers resulted in varying degree of transcriptional effects on the target gene as well as on the other enhancers in the network in non-redundant manner suggesting an established hierarchy among these three enhancers. Further, Jmd3, a histone demethylase binds on lead enhancer ECAD9by directly interacting with its eRNA. Jmd3 competitively displaces Ezh2 on ECAD6 which results in its activation. In summary, we propose that enhancers within super-enhancer act on target genes in hierarchy. The looping among enhancers is essential to exercise not only hierarchy but to also disarm the repressive enhancers of repressive machinery to activate the target genes robustly. [Dimple Notani, Umer Farooq, Kaiwalya Walavalkar, Deepanshu Soota, Anurag Singh, Rajat Man, Sweety Meel, Bharath Saravanan and Jubairul Islam]

Genetics and Development

Neuronal control of muscle development and function: Neurons and Muscles work in harmony and one of the key attributes of the motor neurons is to facilitate the smooth functioning. Using Drosophila as a model we have addressed the motor coordination in muscle development and behavioural output. We have developed free walking behaviour assays in flies and showed the role of GABAergic premotor interneuronal inputs for coordinated walking. On the similar lines we have identified a single pair of interneurons that control the feeding behaviour in flies. In another study we convincingly show for the first time that motor neurons control muscle architecture and have identified the possible role of Hox genes in this process.

Muscle Development and Maintenance: Muscles are multinucleated syncytium formed by fusion of several thousand myoblasts. Myoblasts fusion is key for adult muscle maintenance and repair. On these lines we have made a considerable headway in examining the cellular and molecular basis of adult muscle repair.

Neuronal control of Behaviour: We work on the neuronal connections and underlying plasticity that control long-term memory. We have identified the molecular mechanisms that work in the neurons to control memory and neurodegeneration.

[K. VijayRaghavan, Swetha B. Murthy Gowda, Aman Aggarwal, Ali Asgar Bohra and Umashankar]

Molecular Ecology and Conservation Genetics

India has a population of over a billion people, with only 4% of its area protected as wildlands. Yet the Indian subcontinent harbours incredible biodiversity. Do we know what this diversity is? How has this diversity come to be? How are we impacting this diversity? Over the past several years, we have conducted research that has helped identify cryptic species and genera of birds and mammals, enhancing our knowledge of India’s natural capital. We have studied the biogeographic origins of species in the Indian subcontinent, with particular attention to biodiversity hotspots. From a conservation perspective, if tigers are to survive anywhere in the world, they will do so in India. Dr. Uma Ramakrishnan’s research on conservation genetics helps identify vulnerable and isolated tiger populations, investigate connectivity in the Central Indian landscape and develop novel conservation genomics methods. In order to answer these questions, the lab conducts fieldwork to sample behavioral, ecological and genomic data from these wild populations. The data is analysed in population genetic and phylogenetic contexts to better understand the evolution, population ecology and conservation of populations. [Uma Ramakrishnan, Jyothi Venugopal Nair, Prachi Srikanth Thatte, Anubhab Khan, Vinay Sagar, Amruta Varudkar, Bela Arora, Atul Kumar Upadhyay, Krishnapriya Tamma, Priyadarshini Gurung, Tanushree Srivastava, Nishma Dahal and Meghna Natesh]

Speciation, Adaptation and Morphological Diversification in Tropical Regions

Diversity is the cornerstone of life on earth. We study how new species are formed, and how organisms diversify to adapt to their abiotic and social environments, which has given rise to spectacular
biodiversity. In the last year we particularly focused on understanding how sexual dimorphism evolves in relation natural and sexual selection (Bhaumik and Kunte 2018), as well as speciation and biogeographic isolation, using a molecular phylogeny of mimetic butterflies. This provided unparalleled insights into how biological communities have evolved in the complex landscape of the Oriental Region (Joshi et al. 2017). We further investigated the developmental genetic mechanisms that control sexual dimorphism and polymorphism in mimetic butterflies (Deshmukh et al. 2018). After discovering that doublesex, a highly conserved gene in the sexual differentiation pathway, has been co-opted to control female polymorphism in Papilio polytes, my lab focused on studying how doublesex and other key genes regulate sexual differentiation and female polymorphism during pupal development. We also finished a very broad analysis of the molecular evolution and structural diversity of doublesex, a master regulator that controls sex differentiation across insects. [Krushnamegh Kunte, Riddhi Deshmukh, Saurav Baral, Vaishali Bhaumik, Dipendra Nath Basu and Athulya Girish]

Insights into the mechanism of small RNA biogenesis and their functions in plants

Plant small (s)RNAs are processed from stem-loop structure containing precursor RNAs or from completely complementary dsRNA substrates by Dicer like (DCL) proteins. sRNAs of Micro(mi)RNA class are produced from structured precursors by DCL1 with the help of dsRNA binding partners. It is not known what determines biogenesis and abundance of sRNAs and miRNAs, beyond a ubiquitous requirement for a stem-loop or a dsRNA structure. We have previously shown that miRNA-miRNA* loop length determines abundance of miRNAs. In addition, we have observed unusually high GC content and specific sequence signatures among plant miRNAs. A specific GC signature is maintained across plant miRNAs by having position specificity for G or C. We show that RNA binding domain 1of HYLI, a dsRNA partner of DCL1, is responsible for the observed GC signature among miRNAs. In support of this observation, hyl1 mutants lack precise processing ability and accumulate miRNAs at much lower levels. Using rice as a model system, we have also identified how dsRNAs are generated from genomic repeats by a novel clade of plant-specific polymerases. Using grapes, Arabidopsis, tobacco and rice as model systems, we have identified that plant miRNAs also regulate secondary metabolic processes that produce important metabolites such as anthocyanins, lignins and flavonoids, by targeting key genes. [P. V. Shivaprasad, Vinoth Kumar, Dr. Melvin Prasad, Debjani Basu, Kannan Pachamuthu, Ashwin Nair, Anushree N., Varsha T., Vivek G. Swetha Chenna, Sujith T. N. and Vikram]

Development of the Inner Ear

We are interested in how the inner ear develops, focusing on the genetic and epigenetic factors that generate specific functional cell types that enable hearing and balance sensation. The specialisation and organisation of cells to form organs that effectively carry out functions vital to life, is a fascinating problem. We investigate the formation of the inner ear as a model for cellular and tissue level differentiation. Using a variety of molecular, cellular, imaging, and computational techniques, our aim is to generate a blueprint of the inner ear that puts into context the physical and molecular responses of the inner ear to the dynamic genetic and epigenetic developmental cues. With this, we can interrogate a range of data across a number of systems to understand congenital hearing impairment in particular and developmental morphogenesis in general. [Rajesh K. Ladher, Debudatta Deb, Saumya Matthew, Suraj R., Varsha N. T., Surjit Singh, Jarnail Singh Saini, Anubhav Prakash, Arockia Catherin, Nishant Singh, Shrividhya Seshadri and Sharada Gopal]

Theory and Modelling of Biological Systems

Computational and Evolutionary Cell Biology

Our work is driven by a two-way engagement between quantitative hypotheses (predictions of mathematical models) and experimental biological data (sequences, images, quantitative measurements). Today we are one of the leading groups internationally in the mathematical analysis of eukaryotic membrane traffic. Within NCBS I am a member of the Simons Centre for the Study of Living Machines, funded by the Simons Foundation whose mission is to support the application of mathematics across disciplines. Representative projects are:
1. The origin of eukaryotes (with G. Dey, B. Baum, UCL; Trends Cell Biol)
We studied the genome of Lokiarcheota, recently identified as the closest known cousin to the archaeal ancestor of eukaryotes, and found that molecular components borrowed from both archaea and bacteria were gradually deployed to new uses, including membrane traffic.

2. Integration of mitochondria with the host cell (with R. Purkanti, NCBS; PNAS)
We reconstructed the primordial mitochondrial division apparatus by studying the evolution of dynamin, the protein which drives mitochondrial scission in all extant eukaryotes.

3. Organizing principles of eukaryotic membrane traffic (with: R. Ramadas; Biophys. J.)
Our biophysical models have suggested that gene duplication could drive the segregation of existing membranes into distinct compartments.

4. Statistical cell biology and the evolution of the Golgi apparatus (with S. Mani; eLife)
We statistically sampled tens of thousands of parameter combinations in a Boolean representation of vesicle traffic to understand the evolution of the Golgi apparatus. [Mukund Thattai, Anjali Jaiman, Sachit Daniel, Rahul Kumar, Sachin Rawat, Pragati Dembla, Shruti Malviya, Ansuman Biswas and Ramya Purkanti]

Computational Approaches to Protein Science

Genome sequencing projects provide a large amount of data on sequence information of genes in various model organisms. Our laboratory is interested in enabling functional characterization of gene products and to perform in-depth studies of mechanism of action of enzymes through structural analysis. The three-dimensional modelling and molecular dynamics provides structural rationale for its auto inhibition (Jarjapu and Sowdhamini, 2018a). We have also developed three-dimensional models of a protein, TRIF, which is involved in immunity (Jarjapu and Sowdhamini, 2018b). Further, we have now participated in a collaborative effort, with Dr. Axel Brockmann’ laboratory, to perform cross-comparisons between solitary and social honeybees (Karpe et al., 2018). [R. Sowdhamini, Mahita Jarjapu and Snehal Karpe]

Collective dynamics in living matter: activity, information flow and populations

Our research program aims to understand the organization and function of living matter using the tools and perspectives of complexity science, disordered systems, statistical mechanics and dynamical systems. We view biological entities as a truly unique state of active, adaptive matter; cells, biological tissues, coordinated animal groups and interacting populations (ecology) are a form of complex material and dynamical system with emergent properties that arise from mechanical, biochemical and socially mediated interactions between individuals. We pursue this perspective via two complementary approaches:

1. We construct de novo, synthetic mimics of living matter to study the minimal ingredients for self-assembly, computation, feedback, and evolvability.
This serves as a kind of synthetic biology from a physical viewpoint and is likely to shed light on early evolution and the transitions therein. The focus is on understanding and duplicating, using synthetic inanimate components, the emergence of specific, quantifiable, and characteristic properties of living matter, rather than understanding how life itself emerges from its basic molecular building blocks. This is an important distinction from in vitro reconstitution approaches that have characterized many biophysical studies. The problem then naturally lends itself to the framework of statistical physics in which the key properties of the organization of living matter may be described.

2. We probe the physical basis of organization in biological systems. This represents a kind of physical biology which will allow us to quantitatively identify the broadly universal features of biological systems, similar to statistical mechanical approaches in physics. The approach is to make careful measurements on well-chosen biological phenomena and to use theories rooted in non-equilibrium statistical physics and dynamical systems to understand the data. Often, the experimental data requires the development of new theoretical ideas.

Our goal is to weave these two threads into a tapestry that captures many essential features of a theory of the organization and dynamics of living matter. [Shashi Thutupalli, Manoj Kumar, Godwin Stephenson, Anupam Singh, Charuhasini Gopal Kulkarni, Chittaspandini Gopal Kulkarni, Ashwini Krishna, Vidhya Lakshmi, Shashwat Kumar, Chandan Reddy, Kushal Applineni, Aniruddh Murali]

Ecology and Evolution

Terrestrial ecosystems and community ecology

Can our ecosystems cope with the challenges of ever-expanding human activities? We work on understanding the dynamics of grasslands, forests and mixed tree-grass ecosystems, their responses to changes in climate, and what this means for their future distribution and functioning. Our group has established long term experimental and monitoring programs in ecosystems that span a rainfall gradient in peninsular India, from savannas to wet tropical forests, to address fundamental questions about how these forests are structured, and how they are responding to changes in climate and other directional environmental drivers, including nutrient deposition. Our recent experimental work, using tree seedlings of native N-fixing and non N-fixing savanna species, has shown that atmospheric Nitrogen (N) and P deposition (P) can elicit fundamentally different responses in these two functional groups. N-fixers are co-limited by both N and P availability, but have remarkably stable foliar chemistry that remains unchanged with external inputs of nutrients (Varma et al, 2017, Tiruvaimozhi et al. 2018). Non N-fixers on the other hand, are only limited by N, and respond to increasing N availability by increasing tissue N concentrations, but decreasing tissue P concentrations (Tiruvaimozhi et al. 2018).

These results suggests that long-term N and P deposition can cause directional shifts in the relative abundance of these two functional groups in the future, with attend implications for nutrient and carbon cycling in savanna and dry forest ecosystems. [M. Sankaran, Yadugiri V. T., M. Raghurama and Atul Joshi]

Unraveling the ecological and genetic basis of adaptation

Organisms frequently face new, changing or otherwise challenging environments, which are thought to drive a large proportion of evolutionary adaptations. However, different populations and species often respond differentially to the same environmental change, potentially altering their evolutionary trajectories. For instance, some organisms flourish in new environments, whereas others go extinct. What factors determine individual and population-level responses, and what are the processes and molecular mechanisms that mediate adaptation to new habitats? We address evolutionary processes and constraints acting at three different levels: (1) genetic and genomic features that can limit cellular growth, (2) phenotypic and genetic tradeoffs that may constrain adaptation, and (3) interspecies associations that may either limit or facilitate population growth and establishment. Using laboratory experiments and bioinformatics analyses, we quantified the impacts of codon use, tRNA pools and GC content on bacterial translation and growth. In two diverse organisms (E. coli and flour beetles), we found that genotypic and phenotypic tradeoffs are surprisingly rare during the early stages of evolutionary change, and may...
not constrain adaptation as often as expected. Finally, in laboratory experiments with flour beetles, we documented the first observed instance of the establishment of host-gut bacterial associations, and (separately) the rapid evolution of immune memory against a bacterial pathogen. [Deepa Agashe, Gaurav Diwan, Saurabh Mahajan, Mrudula Sane, Aparna Agarwal, Imroze Khan and Arun Prakash]

**Chemical Ecology of plant-insect interactions**

Our lab works focuses on chemically mediated plant-insect interactions. We recently uncovered an interesting mutualistic relationship between ants and plants while studying seed dispersal mechanisms. We found that ants function as secondary seed dispersers and plants in turn provide them with fatty-acid rich reward on the seed. This fatty acid rich appendage on the seed is known as the elaiosome. We characterized the composition of elaiosome, untangled the cues used by ants to locate the seed and compared various ants and plant species that were involved in this interaction. Our results indicated that olfactory cues play a major role in this interaction and only two of the total ant species found in our study site actually displace the seeds. It was also found that presence of elaiosome could delay germination of the seed underlining the importance of secondary dispersal. Other projects in the lab include impact of heavy metal stress on plant defences, spatiotemporal variation in plant defence responses and elucidating the role of plant volatiles in mediating tri-trophic interactions between plant, insect herbivore and parasitic wasps. [Radhika Venkatesan, Rohit Sasidharan, Shiksha Ajmera, Neha Kalmankar, Praveena, Enakshi Ghosh and Aswathi Menoki]

**The Physics, Neurobiology and Ecophysiology of Insect Flight**

Insects were the first animals to evolve flight and have maintained their mastery over the aerial habitat. Across various scales of size and neural complexity, insects can fly with exquisite speed, control and manoeuvrability. Their wings can flap at frequencies of hundreds of wing beats per second, each wing stroke finely controlled by a sensorimotor system that acquires and processes information at similarly rapid rates. Sensory input is acquired by visual, olfactory, mechanosensory, hygro and thermosensory sensors and communicated to the central nervous system, which generates appropriate motor responses in the form of movement of head, legs, wings etc. Thus, to understand the mechanistic details of even the most mundane observations about flying insects (e.g. flies chasing other flies, moths hovering on flowers, dragonflies or hoverflies guarding territories etc.) requires a multi-disciplinary study of the entire chain of events from sensory input to motor output to flight force generation. My laboratory combines the input from physics, engineering, biomechanics, neurobiology, muscle mechanics and behavioural biology to address diverse flight-related phenomena. To study these questions, we use diverse techniques such as high-speed videography, behavioural measurements, neuroanatomy and neurophysiology. Specific areas of research in the lab include the role of antennal and haltere mechanosensory input in flight control, integration of multi-sensory feedback in flight behaviour, behavioural ecology of insect migration, plant-insect interactions, and mound building behavior in termites. [Sanjay Sane, Dinesh Natesan, Nitesh N. A. Saxena and H. Sant]

**Naturalist-inspired Chemical Ecology**

The NICE is particularly interested in how animals, and especially insects, identify objects across different environments. Their work traverses Himalayan meadows, ecologically sustainable agriculture in Coorg, and pollution in Bangalore - anywhere insects are important, which is nearly everywhere on Earth. This past year saw the culmination of three collaborative projects. First, in collaboration with Karin Nordström at U. Uppsala and Flinders University, we studied how cosmopolitan pollinators can identify objects across climates, which have important implications for our understanding of pollination as a global ecological service (Nordström et al., 2017). Second, in collaboration with Y. Rajashekar at IBSD Imphal (part of the NER-DBT National Program), we identified a volatile from an Indian medicinal plant that targets both the sodium-potassium pump and the insect olfactory receptor complex, rendering it both toxic and behaviorally active to multiple insect orders. Finally, in collaboration with Uma Ramakrishnan at NCBS, we have established a pipeline for large scale field sampling of volatiles that has allowed us to assess odor profiles of blackbuck mating territories in Rajasthan (Nair et al., 2018). [Shannon Olsson, Aditi Mishra, Hinal B Kharva, Geetha G. T., Pavan Kumar Kaushik and Srishti Batra]
Members

Research Scholars


Visiting Fellows

**Junior Research Fellows / Senior Research Fellows**


**M.Sc. by Research**

Bela Arora, Shiksha Ajmera, Manisha Goel, Rohit Sadasiharan, Vikram

**M.Sc. in Wild Life and Conservation**


**Scientific and Technical**


**Administrative and Auxiliary Staff**


**Pachmarhi Staff (transferred to NCBS)**

National and International Involvement

Deepa Agashe
1. Associate Editor, Molecular Biology and Evolution
2. Editor, Matters
3. Editor, Molecular Biology and Evolution Special issue on the Genetics of Adaptation
4. Member, Society for the Study of Evolution, American Society of Naturalists, and the Society for Molecular Biology and Evolution

Anjana Badrinarayan
Member, Question paper setting committee, DBT JRF exam

U. S. Bhalla
1. Board, Reviewing Editors, eLife
2. Board, Reviewing Editors, eNeuro Journal of Computational Neuroscience
3. Schwartz Prize Selection Committee, Society for Neuroscience
4. Chair, Department of Biotechnology Neurobiology Task Force
5. Member, SERB Programme Advisory Committee, Animal Sciences

Sumantra Chattarji
1. Co-Chair, Task Force on Neuro-Disease Biology, Department of Biotechnology, Govt. of India
2. Member, Steering Committee, Inst. for Stem Cell Biol. and Regenerative Medicine, Bangalore
3. Member, NCBS–Committee on Administration & Laboratory Management Coordinator, National Mouse Research Resource Facility, NCBS, Bangalore
4. Chair, Institutional Animal Ethics Comm., Inst. for Stem Cell Biol. and Reg. Medicine, Bangalore
5. Faculty in-charge, NCBS-inStem Animal Care Facility
6. Member, Scientific Advisory Board, Ashoka University, India
7. Member, Scientific Advisory Board, Pfizer-India
8. Wellcome Trust-DBT India Alliance, Early Career Fellowship Selection Committee
9. Member, Committee on Animals in Research, Society for Neuroscience
10. Member, Professional Development Committee, Society for Neuroscience
11. Member, International Affairs Committee, Society for Neuroscience
12. Member, Women in Neuroscience Subcommittee, Society for Neuroscience
13. Member, Workforce and Training Working Group, Society for Neuroscience
14. Member, Advisory Group on Member Value, Society for Neuroscience Annual Meeting
15. Member, Advisory Group, Society for Neuroscience
16. Member, Joint Society for Neuroscience International Affairs Committee and NAS U.S. National Committee for the International Brain Research Organization (IAC/USNC-IBRO)
17. President and past Secretary, Molecular and Cellular Cognition Society – Asia
18. Council member, Molecular and Cellular Cognition Society, USA
19. Member, Editorial board, Current Opinion in Physiology
20. Member, Editorial board, Journal of Physiology
21. Member, Editorial board, Journal of Neurophysiology
22. Member, Editorial board, Molecular Brain
23. Member, Editorial board, IBRO Reports
24. Member, Editorial board, Science Matters
25. Member, Editorial board, Journal of Neuroscience Methods
26. Member, Editorial board, Neural Plasticity
27. Member, Editorial board, Journal of Psychiatry and Neuroscience

Ranabir Das
1. Member, Editorial board, Journal Science Matters
3. Member, American Chemical Society (ACS)
4. Member, National Magnetic Resonance Society (NMRS)

Gaiti Hasan
1. Member, DBT Task Force, CoE for Basic Sciences, Oct 2016 - to date
2. Member, DBT Recombinant DNA Advisory Committee, Jan 2016 – to date
3. Member, DBT Task Force, Genome editing technologies, July 2014 – to date
4. Member, Scientific Advisory Committee, National Institute for Biomedical Genomics, Kalyani, West Bengal, March 2013 – to date

Sudhir Krishna
1. Member, SERB Indo-U.S. postdoctoral fellowship selection committee
2. Member, DBT/Wellcome India Alliance Senior and Intermediate fellowship committee

Krushnamegh Kunte
Invited Associate Editor, Molecular Biology and Evolution, Special issue on Genetics of Adaptation

Rajesh Ladher
1. Asian Editor, Development, Growth and Differentiation
2. Member, Editorial Board, Developmental Dynamics, Neural Development
3. Member, Organising Committee for the 2018 Indian Society for Developmental Biology Meeting

Dimple Notani
Member, Editorial advisory board, Life Science Alliance

Shannon Olson
1. Review Editor, Frontiers in Integrative Neuroscience, Frontiers in Physiology, Halteres
2. Member, Coffee Board of India Steering Committee

Raghu Padinjat
1. Member, Biochemical Society, USA
2. Member, Indian Society for Developmental Biology

Vijay Ragharan
1. Principle Scientific Advisor to Prime Minister
2. Fellow, The World Academy of Sciences
3. Fellow, Indian academy of sciences
4. J. C. Bose Fellow
5. Foreign associate of the US National academy of Sciences
6. Senior Editor, eLife Journal

Vinothkumar Kutti Ragunath
Member, Electron Microscopy Society of India

Sanjay Sane
1. Member, Editorial board, Journal of Experimental Biology, 2018 – to date
2. Member, Editorial board, Journal of Bionic Engineering, 2009 – to date
3. Member, Editorial Board, Biology Letters, 2013 – to date
4. Member, Editorial Board: Journal of Neurophysiology, 2016 – to date
5. Review editor, Frontiers in Neural Circuits, 2009 – to date

Mahesh Sankaran
1. Coordinating Lead Author for the Land Degradation and Restoration Assessment of the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES); chapter on ‘Direct and indirect drivers of land degradation’
2. Review editor, IPCC AR6 Special Report on “Climate change, Land use and Food security”
3. Associate Editor, Journal of Ecology
4. Subject Editor, Biotropica

P. V. Shivaprasad
1. Editorial member, Science Matters
2. Guest Editor, Frontiers in Plant Sciences
3. Member, Board of Studies, Mysore University and IBAB, Bangalore

R. Swadhamini
1. Member, Bioinformatics Taskforce, Department of Biotechnology, India
2. Member, Neuroscience Taskforce, Department of Biotechnology, India
3. Co-opted Member, Biophysics, Department of Science and Technology, India
4. Member, Wellcome Trust-Department of Biotechnology India-Alliance for Early Career Fellowships
5. Member, Indian National Science Academy for Young Scientist Award Nominations and INSA Fellows

Varadharajan Sundaramurthy
1. Scientific editor, Matters
2. Reviewer, Cellular Microbiology
3. Reviewer, Frontiers of infection microbiology
4. Reviewer, Journal of Biomolecular Screening
5. Reviewer, Scientific Reports, Matters
6. Reviewer, International Journal of Medical Microbiology
7. Reviewer, Cytometry
8. Grant proposal reviewer, Department of Biotechnology (DBT), ASTAR

Mukund Thattai
1. Board Member, Trustee, Raman Research Institute Trust, 2018 – to date
2. Management Board, NCBS, 2017 – to date
3. Academic and Research Council, Trans-Disciplinary University, 2016 – to date
4. Board of Studies, Srishti Institute of Art, Design and Technology, 2015 – to date
5. Programme Committee, Bangalore International Centre, 2016 – to date

Vatsala Thirumalai
1. Board of reviewing editors, eLife
2. Member, Editorial Board, Journal of Neurophysiology
3. Reviewing Editor, Frontiers in Neural Circuits

Shashi Thuttupalli
1. Journal Referee, Central European Journal of Physics
2. Journal Referee, Chaos
3. Journal Referee, elife
4. Journal Referee, Microfluidics and Nanofluidics
5. Journal Referee, New Journal of Physics
8. Journal Referee, Physical Review Fluids
9. Journal Referee, PNAS
10. Member, Grant Proposal Review, Complex Systems
Visits

Anjana Badrinarayan
1. Regulation of DNA double-strand break repair in bacteria. IISER Trivandrum, July 2017
2. Regulation of DNA double-strand break repair in bacteria. NISER Bhubaneshwar, November 2017
3. Regulation of recovery from DNA damage induced stress in bacteria. McGill University, April 2018
4. Regulation of recovery from DNA damage induced stress in bacteria. IISc, May 2018

Hiyaa Ghosh
2. EMBO Conference on Gene regulatory mechanisms in neural cell fate decisions, Alicante, Spain, NCBS funds, 7-10 Sep, 2017
3. Cell symposia on Neuro-Immune Axis, Sitges, Spain, NCBS funds, Sep 17-19, 2017,

Shachi Gosavi
2. Barriers in the folding of serpins to alternative native conformations. Poster at RARE (A biennial conference on modeling rare events), Agra, Dec. 2017

Sandeep Krishna
1. Simons Foundation, April 2017
2. Columbia University, April 2017
3. Yale University, April 2017
4. Guelph University, April 2017
5. Univ. of Illinois, Urbana-Champaign, May 2017
6. ESPCI, Paris, Feb 2018

Sudhir Krishna
1. St. Joseph’s College, Bangalore, March 2018
2. KAVI Centre for clinical research, University of Nairobi, March 2018

Rajesh Ladher
1. RIKEN CDB, Kobe
2. Kwansei Gakuin University
3. University of Cambridge
4. King’s College, London

Shashi Thartipalli
1. KITP Program on Memory Formation in Matter, KITP, Santa Barbara, USA, February, 2018 (2 weeks)
2. Max Planck Institute for Cell Biology and Genetics, Dresden, Germany January, 2018 (1 week)
3. Max Planck Institute for Physics of Complex Systems, Dresden, Germany, January, 2018 (1 week)
4. Max Planck Institute for Dynamics and Self-Organization, Goettingen, Germany, Jan 2018 (1 week)
Invited Talks

Deepa Agashe
1. Investigating the causes of large shifts in bacterial genome GC content. 1st Asian Evolution conference, Shenzen, China, April 2018
2. The incidence and impact of tradeoffs. ICTS School on Population Genetics and Evolution, ICTS, Bangalore, March 2018
3. The ecology and evolution of host-pathogen interactions. Symposium on host-pathogen interactions, NISER, Bhubaneswar, February 2018
4. The ecology and evolution of host-bacterial associations. Indo-French workshop on evolutionary developmental and cell biology, France, January 2018
5. The incidence and impact of tradeoffs. Conference on cellular and integrative biology, Pune, December 2017
6. The unbiased incidence of true tradeoffs in a bacterium. SMBE satellite meeting on microbial evolution, Kaziranga, Assam, Dec 2017
8. Bacterial genome evolution: Reconciling experiments and phylogeny. ESEB meeting, Groningen, Netherlands, August 2017

Anjana Badrinarayan
1. Regulation of DNA double-strand break repair in bacteria. mCube meeting, CDFD Hyderabad, Dec 2016
2. Regulation of DNA double-strand break repair in bacteria. Bose Institute 100 yrs. celebration, Kolkata, October 2017
3. CEFIPRA meeting on genome stability, Bangalore, December 2017
4. Indo-US meeting on transcription, chromatin structure, DNA repair and genome instability, Bangalore, March 2018

U. S. Bhalla
1. Brain activity sequences as a fundamental operation in computation. TCIS Hyderabad Symposium, 27 April 2017
2. Network implications of sequence discrimination by single neurons. ICTS workshop on Physical and Systems Biology (WPSB), Bangalore, June 11-25, 2017
3. How the brain perceives patterns in space and time. Neuroscience symposium at Ramaiah Medical College, Bangalore, 21 June 2017
5. Computing with a self-modifying machine: Multiple scales of plasticity at the synapse. Leopoldina-INSA Symposium “The challenge to learn: New approaches to study the problem of stability vs. plasticity in the brain”, LVPEI, Hyderabad, 28-29 November 2017
7. Multiscale brain computation of sequences, or, Why molecules matter even if you only study neural networks. Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore, Symposium, 5 March 2018
9. Network outcomes of subcellular neural computations. Invited seminar at the Mount Sinai School of Medicine, New York, 19 March 2018

Axel Bruckmann
Molecular mechanisms underlying daily foraging in honey bees, InSearch – one-day symposium on insects in research, JNCASR, Bangalore, 5 January 2018

Sumantra Chattarji
1. Stress: Past, Present and Future Directions. Princeton University, USA, August, 2017
4. The Simons Initiative for the Developing Brain, Patrick Wild Centre, University of Edinburgh, UK, August, 2017

Ranabir Das
1. Exploiting the host signaling pathways by the Herpes Simplex Virus. EMBO conference on Ubiquitin and SUMO: From molecular mechanisms to system-wide responses, Croatia, 15-19 September, 2017
2. Exploiting the host signaling pathways by the Herpes Simplex Virus. Frontiers in Molecular Biology, IISER Kolkata, January 19-21 2018
1. Conformational dynamics in the Endoplasmic Reticulum Associated Degradation pathway and its effects on protein folding. 24th Annual NMRS Meeting, IISER Mohali, February 16-19, 2018

**Hyaa Gbath**

1. Making new neurons in the adult brain: regulations and responses. Mysore University, March 23, 2018
2. Making new neurons in the adult brain: regulations and responses. Maharaja Sayajirao University of Baroda (MSU), March 15, 2018
3. Making new neurons in the adult brain: regulations and responses. Stem Cell Symposia. NCBS-inStem, Bangalore, February 1, 2018
4. The mammalian brain: A cell-molecular perspective. National Symposium on Recent Advances in Biochemistry, Genetics and Systems Biology: BiosynGene Pondicherry University, Feb 28, 2018
5. Inside the mammalian brain: the well-being of the new and the old neurons. Conference on Aspects of gene and cellular regulation, The Institute of Mathematical Sciences, Chennai, Jan 12-13, 2018
6. The adult brain and a multifaceted transcription factor. TIFR – Natural Sciences Faculty Colloquium, TIFR, Mumbai, Oct 4, 2017

**Shachi Gosavi**

2. Understanding HDX-NMR data using protein simulations. Indo-German workshop on Computing in Chemistry, Biology and Medicine, IIIT Hyderabad, Hyderabad, November 2017
3. The effects of functional residues on the folding landscapes of proteins. 60th Birthday Symposium for Jose’ Onuchic, Rice University, Houston, TX, USA, January 2018
4. Understanding protein folding and dynamics using computational methods. An Interdisciplinary approach to Biological Sciences, Indian Association for the Cultivation of Science, Kolkata, February 2018
5. Understanding the folding of a protein with a metastable native state. Indian Biophysical Society Meeting, IISER Pune, March 2018

**Gaiti Hasan**

1. To fly or not to fly – decision making in a small brain. DST-INSPIRE Camp, Punjab University, Chandigarh, April 2017
3. To fly or not to fly – decision making in a small brain. Univ. of Bourgogne, Dijon, France, July 2017
4. Regulation of Store-operated Ca2+ entry by Septins. EMBO workshop on Septins, Berlin, Germany, October 2017
5. Central Dopaminergic neurons and Store-operated Ca2+ entry in fly flight. Inaugural Asia-Pacific Drosophila Neurobiology Conference, Wuhan, China, October 2017
7. To fly or not to fly – decision making in a small brain. Indian Drosophila Biology Meeting, IISER Bhopal, December 2017
8. Wiring up a small brain for making decisions, Plenary talk at the IBRO – Neuroscience School, University of Pune, March 2018

**Sandeep Krishna**

1. The chemical basis of metabolic interdependence. Les Houches meeting on Evolution of Diversity, Les Houches, France, February 2018
2. Hysteretic oscillations in a well-mixed population of budding yeast. 5th Indian Statistical Physics Community meeting, ICTS, Bangalore, February 2018
3. Mechanical interference of transcription by polymerases. India iGEM Meetup, IISER Pune, July 2017
4. Diversity in bacteria-virus ecosystems may be facilitated by restriction-modification systems. Dept. of Biology, IISER Pune, July 2017

**Sudhir Krishna**

1. St. Joseph’s College, Bangalore, March 2018
2. KAVI Centre for clinical research, University of Nairobi, Nairobi, March 2018

**Krushnamegh Kunte**

2. Evolution of Defence Ensembles in Papilionidae: Microevolutionary Trend at a Macroevolutionary Scale. Bi-annual meeting of the European Society for Evolutionary Biology, Paris, France, July 2017
3. Allopatry, Reproductive Isolation and Systematics Delimiting Species in the Biogeographically Complex Indo-Australian Region. Third International Conference on Southeast Asian Gateway Evolution (SAGE 2017), Bogor, Indonesia, 28 August – 1 September, 2017
4. Molecular Evolution and Functional Diversity of doublesex, a Master Regulator of Polymorphisms in Insects. Departmental Seminar, Department of Biological Sciences, National University of Singapore, 8 September 2017
5. Evolutionary Assembly and Ecological Dynamics of Butterfly Mimicry Rings. Departmental Seminar,
Department of Biology, Colorado State University, Fort Collins, USA, 30 January 2018
6. Molecular Evolution and Functional Diversity of doublesex: A Master Regulator of Polymorphisms in Insects. Departmental Seminar, Department of Entomology, University of Georgia, USA, 29 Jan 2018

Rajesh Ladher
2. Protein Trafficking in the Inner Ear Hair Cell. CCRB Seminar, King’s College, London, 5 September, 2017
3. The Formation of the Mechansensory Hair Cell. BSBE Winter Workshop, IIT Kanpur, 16 December, 2017
4. Coordinating Cell Shape during Early Inner Ear Morphogenesis. NCBS Annual Talks, NCBS, 3 – 5 January, 2018

M. K. Mathew

Satyajit Mayor
1. Building membrane domains at the surface of living cells triggered by signaling receptors. Purdue Institute of Inflammation, Immunology and Infectious Disease, Indianapolis, USA, 3 July 2017
6. Building an interdisciplinary research program to study life at the cell’s edge. Foundation day of IBAB, Bangalore, 17 March 2018

Dimple N. N. Notani
1. Role of transcriptional enhancers in gene regulation, Aspects of Gene and Cellular Regulation. The Institute of Mathematical Sciences, Chennai, January 12-13, 2018
2. Enhancer mediated gene regulatory networks. Transcription, DNA repair and Genome Surveillance, Indian Institute of Sciences, Bangalore, 6-10 March, 2018
3. Role of transcriptional enhancers in gene regulation. 7th Symposium of the DNA society of India. Importance of DNA fingerprinting, cataloguing and utilization of the bioresources of North-East India, IASST, Guwahati, 17-18 November, 2017
4. Transcriptional enhancer networks in gene regulation, 3rd Biennial InDRC 2017 Meeting. IISER, Bhopal, 6 – 9 December 2017

Shannon Olsson
1. When changing your mind changes your species: A 150-year-old mystery of intrigue and apples. Biodiverse, IIT Guwahati, January 27-29, 2018
2. Flipping the switch on host preference in tephritid fruit flies. Entomol. Soc. America, Denver, CO, US, November 5-8, 2017
3. From Insect Dreams to Virtual Reality. ESITO, Calgliar, Sardinia, September 17-22, 2017
5. Commencement Address, Dr. G. P. Shetty Endowment Lecture, GPS Inst. Ag. Man., Bangalore, Sep 25, 2017
7. Salon Speaker, SPBN Forum, Young Presidents’ Organization, Bangalore, June 29, 2017

Raghun Padinjat
1. Phosphatidylinositol 5-phosphate 4-kinase regulates early endosomal dynamics during clathrin-mediated endocytosis. Indian Society for Developmental Biology Meeting, Pune, June, 2017
2. 2nd Annual DELTAS Grantees Meeting, African Academy of Sciences & Wellcome Trust, Ghana, July 2017
3. Accelerator program for Discovery in Brain disorders using Stem cells: A novel resource for investigating the cellular basis of neurological disease. International Congress of Cell Biology, Hyderabad, January 2018
4. Tuning of Lipid Transfer Reactions at Membrane Contact Sites in Drosophila Photoreceptors. Keystone Meeting on Phosphoinositides, Taos, New Mexico, February 2018

Vinodkumar Katti Ranganath
1. Electron Microscopy Society of India, Chennai, 2017
2. National Institute of Immunology, 2017
3. EMBL-DBT Symposium, New Delhi, 2017
4. Realising the full potential of electron cryomicroscopy, International congress of Cell biology, Hyderabad, 2018
5. Bio-gene Sys, Department of Biochemistry and Molecular biology, Pondicherry University, February 2018

Arati Ramesh
1. Structure to signaling – regulating metal homeostasis through RNA. MBU, IISc, Bangalore
2. Structure to signaling – regulating metal homeostasis through RNA. Center of Infectious disease and research, IISc, Bangalore
3. Structure to signaling – ANTAR regulation in mycobacteria. 100th year symposium, J. C. Bose Institute, Kolkata, October 2017
4. Structure to signaling – regulating metal homeostasis through RNA. IT Across Scales, Kolkata

Sanjay Sane
2. Strategies for odor source location in fruit flies. Lund University, Sweden, 14 September, 2017
3. How flies determine the location of an odor source. King’s College, London, 13 April 2017

Aswin Sai Narain Seshaasee
1. Genomics, Post genomics and back to the basics. HBCSE Mumbai, July 2017
2. Bacterial Evolution in Deep Stationary Phase. Conference on infectious diseases, IISc, Bangalore, November 2017
3. Combinatorial control of transcription in bacteria. IISER Tiruvananthapuram, November 2017
4. Evolution of bacterial chromosome organization. ICCB meeting, Hyderabad, January 2018
5. Bacterial Evolution in Deep Stationary Phase. Conference on antimicrobial resistance, SASTRA, Thanjavur, January 2018
6. Chromosome organisation in bacteria. Mysore University, Mysore, February 2018
7. (a) Bacterial Evolution in Deep Stationary Phase and (b) Evolution of bacterial chromosome organisation at Shinshu University, Ina and Ueda campuses, Japan, March 2018

P. V. Shiruprasad
1. Epigenetics and transcriptional silencing. Workshop for PG teachers, Crop Physiology, University of Agricultural Sciences, Bangalore, 9 March 2017
2. Insight into small RNA biogenesis and their functions in plants. EMBO conference on ‘Macro and micro regulators in plants’, RGCB, Trivandrum, February 1-4, 2017

3. Epigenetics and small RNA variations in plants. Workshop on genomics, Department of Genetics, University of Agricultural Sciences, Bangalore, 17 March 2017
4. Insight into small RNA biogenesis and their functions in plants. National Conference on Biotechnology, IUCGGT, University of Kerala, Trivandrum, March 2, 2017
5. Molecular Mechanisms of rice domestication. Pan TIFR Biologists meeting, TIFR Hyderabad, 24 - 26 April, 2018
6. miRNA-mediated regulation of plant secondary metabolism. IISER Pune, 4 December 2017
7. miRNA-mediated regulation of plant secondary metabolism. RNA meeting, 12 February 2018
8. miRNA-mediated regulation of plant secondary metabolism. University of Hyderabad, 26 April 2018
10. miRNA-mediated regulation of plant secondary metabolism. OMICS gateway-Tools and Techniques for Modern Agriculture, GKVK, 23 March 2018
11. Biogenesis and functions of plant small RNAs. Bangalore University, Workshop for PG teachers, 23 February 2018
12. Insights into miRNA biogenesis and their functions in plants. ICPDB Conference, NISER Bhubaneswar, December 13, 2017
13. Insights into miRNA biogenesis and their functions in plants. ‘Plant-Insect-Microbe interactions’, NCBS, December 17, 2017
14. Insights into miRNA biogenesis and their functions in plants. RNA meet, BHU, Varanasi, 27 October 2017
15. Experimental approaches in utilization of genomic resources for improvement of horticultural crops. University of Horticultural Sciences, Bagalkot, 22 August 2017
16. Application of Biotechnology in Horticulture Use of small RNA molecules to remodel plant development and metabolism. Prof. M.H. Marigowda Memorial Lecture, Lalbagh, Bangalore, 22 June 2017

Varadharajan Sundaramurthy
1. The intersection of intracellular mycobacterial trafficking routes with host endocytic pathways. Cold Spring Harbour Asia, Suzhou, China, 17 April 2017
2. Endo-lysosomal control of intracellular mycobacterial infection. NCBS Lipid center meeting, NCBS, Bangalore, 29 September 2017
3. Lysosomal control of mycobacterial infection, Lysosome biology meeting. JNCASR, Bangalore, 2 October 2017
4. Endo-lysosomal control of intracellular mycobacterial infection. CIDR-Infosys meeting, IISc, Bangalore, 22 December 2017
5. Autophagy-Endocytosis nexus in the control of
intracellular Mycobacterial infection. EMBO autophagy conference, ILS, Bhubaneswar, December 2017
6. Lysosomal control of intracellular Mb. RePORT India consortium meeting, NIH meeting, ICGEB, New Delhi February 2018
7. Indian effort for assay development for P. vivax liver stage. Gates liver stage consortium meeting, Bangkok, March 2018
8. Sub-cellular interactions during Plasmodium liver stage development. Meeting to celebrate 80th birthday of Prof. Gec Pee, IISc, Bangalore, March 2018

Mukund Thattai
1. Dynamical models of eukaryotic membrane traffic. ICTS School on Dynamics of Complex Systems, Bangalore, May 2017
2. Possible and impossible cells. Lederberg Von Neumann Symposium, Rockefeller University, June 2017
3. Possible and impossible cells. Department of Molecular Genetics and Cell Biology, University of Chicago, June 2017
4. Possible and impossible cells. IIT Bombay, July 2017
5. Possible and impossible cells. HFSP Fellows’ Meeting, Lisbon, Portugal, July 2017
6. Possible and impossible cells. JNCASR, Bangalore, July 2017
7. The Golgi apparatus – could form preceed function? Lipid Centre Meeting, Bangalore, September 2017
8. Possible and impossible cells. Computer Science Colloquium, TIFR, Mumbai, October 2017
9. A public engagement roadmap for scientists. Indian Academy of Sciences, Bangalore, October 2017
10. Possible and impossible cells. Bose Institute Centenary Celebrations, Kolkata, December 2017
11. Molecular archaeology: using genomes to reconstruct cellular life. ICTS@10, ICTS, Bangalore, January 2018
12. Possible and impossible cells. International Conference on Cell Biology, Hyderabad, January 2018
13. Possible and impossible cells. Traffic within and between cellular compartments, IISER Pune, Jan 2018
14. Possible and impossible cells. Evolutionary Developmental Cell Biology Meeting, Banyuls Sur Mer, France, February 2018
15. Cell division and cell death: two sides of a random coin.

Visitors’ Program, Delhi University, March 2018

Vatsala Thirumalai
2. From molecules to behaviour: Mechanistic insights from zebrafish models of human neurological conditions. Bio-Gene-Sys 2018, University of Pondicherry, Pondicherry, 28 February 2018

Shashi Thutupalli
1. Collective behavior and self-organization in synthetic active matter. Conference on Collective Behaviour, ICTP, Trieste, Italy, 7 May 2018
2. Self-organized structures of active matter via controlled phase separation. Simons Foundation Conference on Theory and Biology, New York City, USA, 13 April 2018
4. Disordered systems far from equilibrium. French-Indian meeting on plasticity and rheology in amorphous solids, in connection with glassy dynamics, Grenoble, France, 27 June 2017
5. Bacterial Morphogenesis: Collections and single cells. ICTS Program on the Dynamics of Complex Systems, ICTS, Bangalore, 23 June 2017
6. Collective dances far from equilibrium. Frontiers in Living and Active Matter, IBS for Soft and Living Matter, Ulsan, South Korea, 23 February 2017

Radhika Venkatesan
1. Spatiotemporal variation in plant defence responses, ICAR, Umiam, Meghalaya, April 18, 2018
2. Alternate route to GLV biosynthesis confers resistance against insect herbivores. GRC on plant volatiles, Lucca, Barga, Italy, Feb 7, 2018
3. Chemical ecology of interactions. Max Planck Institute for chemical Ecology, Jena, Feb 15, 2018

Conferences Organized by the Centre

Max Planck Partner Group Symposium
NCBS, Bangalore, 14 April 2017

Neuroscience across Scales
NCBS, Bangalore, July 17–19, 2017

Computational Approaches to Memory and Plasticity (CAMP)
NCBS, Bangalore, July 19–August 03, 2017

1st SPEEC-Up student competition
NCBS, Bangalore, August 2017

Structure across Scales
NCBS, Bangalore, October 7–8, 2017
Indo-German meeting on Chemical Ecology
NCBS, Bangalore, November 16–17, 2017

NCBS Annual Meeting
NCBS, Bangalore, January 3–5, 2018

Opening Symposium and Inauguration of CryoEM facility
NCBS, Bangalore, January 24–25, 2018

Indo-Africa Health Science Meeting
NCBS, Bangalore, January 30–31, 2018

Non-DAE Research Projects

Deepti Agashe
Bacterial genome evolution in host-associated communities. Wellcome Trust/DBT India Alliance, 2018 – 2022

Reety Arora
Elucidating the link between stemness and carcinogenesis - Through the lens of an oncogenic virus. ECF, Wellcome Trust-Department of Biotechnology India Alliance, 01.07.2015 – 30.06.2020

Baisak B.
Dissecting endogenous and pathogenic mechanisms of Atx2 prion-domain. SERB, 12.10.2015 – 12.9.2018

Lakshmi B.
Quantitative analysis of Plasmodium and hepatocyte interactions in vivo by combining 3D image analysis and structural bioinformatics approach. NPDF, SERB, 01.09.2016 – 31.08.2018

Anjana Badrinarayanan
Regulation of error-prone DNA repair in bacteria, Human Frontier Science Program, 2018 – 2021

Harsha Bajaj
Quantification of substrate across membrane proteins. BIOCARE, DBT, 19.02.2018 – 18.02.2021

U. S. Bhatia
Optogenetic analysis of memory formation (Co PI: Vatsala Thirumalai). Department of Biotechnology, 5 years

Poulomi Biswas
Unravelling the molecular mechanism behind activity of the viral ubiquitin ligase. ICP0, NPDF, SERB, 02.06.2017 – 01.06.2019

Axel Brockmann
Sequencing the genome of the Himalayan giant honey bee, Apis laboriosa with a special focus on chemosensory receptors and circadian clock genes (with Jharna Chakravorty (RG University, Arunachal Pradesh), R. Sawdhani). DBT Twinning Programme, DBT, 2016 – 2019

Anchal Chandra
Modulation of physiological and oncogenic Ras protein signaling via plasma membrane clustering. ECF, Wellcome Trust-Department of Biotechnology India Alliance, 01.03.2017 – February 2022

Dhananjay Chaturvedi
Zfh1 as an identifier of Drosophila Satellite Cells in a Model of Muscle Repair. NPDF, SERB, 01.05.2017 – 30.04.2019

Himanshu Chhattani

Savita Chib
Genome-wide approaches to investigate modulation of global gene regulatory networks in E. coli under prolonged stationary-phase. SERB, 25.05.15 – 24.05.18

Ranabir Das
1. Investigating the nucleation mechanism of homologous recombination in DNA repair. Ramalingaswamy fellowship, Department of Biotechnology, 2014-2019
2. Investigating the molecular mechanism of lipid transport by the RDGB protein in the Drosophila photoreceptor (with Raghu Padinjat). Department of Science and Technology, 2016 – 2019

Hiyaa Ghosh
1. Role of E-protein in the neuro-immune context. Ramanujan fellowship, DST, Contingency for 5 years (starting 15.02.16)
2. Exploring E-proteins in microglial homeostasis. Early Career Research Grant, SERB-DST, 3 year (starting 20.03.17)

Shachi Gosavi
Understanding and design of domain-swapping in biomolecules. SERB-EMR, March 2017 – March 2020

Saikat Haldar
Targeted Metabolomics and Biotransformation of Toxic Terpene Glycosides from Common Indian Ferns, NPDF, SERB, 03.04.2017 – 02.04.2019

Gaiti Hasan
1. Olfactory modulation of insect flight (with Sanjay Sane, Serge Birman (ESPCI, Paris) and Jean-Francois Ferreur (Univ. of Bourgogne, Dijon, France)). Indo-French Centre for the Promotion of Advanced Research – CEFIPRA/Department of Science and Technology grant for studying, May 2014 – April 2018
2. Molecular genetics of intracellular calcium signaling in neurons with application to neurodegeneration in humans. Department of Biotechnology, August 2013 – July 2018
3. A longitudinal study of molecular and cellular changes in intracellular calcium signaling with neurological correlates in an SCA1 cohort in South India (with Mathew Alexander and Sumita Danda (Christian Medical College, Vellore)). Dept. Of Biotechnology, Sep 2012 – Aug 2018

Nandashree Kasturacharya

Sudhir Krishna

Pramod Kumar
Regulation of endosomal transport by a novel phosphoinositide kinase. NPDF, SERB, 01.04.2016 – 31.03.2018

Sanjeev Kumar
Exploring the role of evolutionary selection on the amino acid diversity at specific positions in the structures of protein: a case study with triosephosphate isomerases. NPDF, SERB, 01.04.2017 – 30.03.2019

Krishnamoorthy Kante

Megha
Role of IP3 receptor mediated neuropeptide release in Drosophila feeding and metabolism. ECF, Wellcome Trust-Department of Biotechnology India Alliance, 01.04.2013 – 31.03.2018

Dimple Notani
Understanding IFNγ mediated enhancer-code to activate and repress target genes. Wellcome-DBT IA Intermediate Fellowship, 2016-2021

Shannon Olson
1. Insect VR. Microsoft Foundation, 2017-2018
2. Impact of Pollution on Pollinator. Tata Trusts Foundation, 2017-2020
3. NER-DBT Chemical Ecology Grant. DBT India, 2015-2020
4. Ramanujan Fellowship. SERB India, 2016-2020

Reghu Padminjat
1. Regulation of Drosophila larval growth and TOR signalling by a novel lipid kinase. Department of Biotechnology, Government of India project grant, 2014 – 2017
2. Co-ordination and control of the phosphoinositide cycle during cell signaling. Wellcome Trust-DBT India Alliance, Senior Fellowship for Basic Research, 2015 – 2020
3. Accelerator program for brain disorders using stem cells (with Sanjeev Jain (NIMHANS) and Mahendra Rao(inStem)), Department of Biotechnology, Government of India, 2016 – 2020
4. Genome Engineering using CRISPR to enable discovery in lipid signaling (with Deptti Trivedi). Department of Biotechnology, Government of India project grant, 2016 – 2019

Ayasha Prasad
Final phase of study that monitors the effects of the invasive Lantana shrub on habitats in southern India. Conservation, Food & Health Foundation Inc, 01.02.2016 – January 2018

Sajeevan R. S.
Engineering stress inducible super promoters for multiple abiotic stress tolerance in plants. NPDF, SERB, 22.05.2017 – 21.05.2019

Vinodkumar Katti Ragunathan (co-PI)
(PIs: S. Ramasamy (Instem), U. S. Bhalke) B-LIFE: Bangalore Life sciences Cluster for multi-scale basic and applied research in Biological Sciences. DBT, India (extension till June 2018)

Diyaa Rajagopal
Investigating the role of plant SNARE proteins in salt tolerance. WOSA, DST, 06.09.2016 – 05.09.2019

Vivek Ramachandran
Non-volant small mammal communities of the Western Himalayas: exploring drivers of elevational richness and community composition. SERB, 01.12.2015 – 30.11.2018
Arati Ramesh
1. DST-SERB Early Career Award, DST, March 2017 – March 2020

Laasya Sambita
Stress-dependent evolution of new traits in bacteria through manipulation of tRNA levels. ECF, Wellcome Trust-Department of Biotechnology India Alliance, 01.07.2015 – 30.06.2020

Sanjay Sane

Mabezh Sankaran
Climatic and environmental controls of carbon budgets and the CO2 source-sink potential of Indian tropical forests. DST SERB, 2017 – 2020

Ishita Sengupta
Probing the aggregation kinetics and conformational changes during the conversion of native mouse prion protein 230231 to workmike fibrils using a spectroscopic approach. IYBA, DBT, 20.09.2014 – 18.03.2018

Aswin Sai Narain Seshasayee
An investigation of the impact of chromosome organisation on global gene expression and evolution of bacteria. Wellcome Trust DBT India Alliance, March 2017 – Feb 2022

P. V. Shiratpreasad
1. Deployment of small RNA and epigenetic variations towards crop improvement. DST, 5 years, 15.7.2013 – 14.6.2018 (74 lakhs)
2. Network grant on ‘small RNAs and epigenetic regulators in rice flower development’. DBT, 5 years, 1.11.2015 – 30.10.2020

Amanjot Singh
Young Scientist project titled “Chaperones and protein handling in condensed liquid state”, Interim Fellowship, Indian National Science Academy, 15.10.2017 – 14.10.2020

Varadharajan Sundaramurthy
1. Assay development for P. vivax liver stage (in collaboration with Susanta Ghosh, National Institute of Malaria Research, Bangalore). Medicines for Malaria Venture, 2015 – 2018
2. Role of autophagy in the intra-erythrocytic cycle of P. falciparum (with Namita Surelia and Ravi Manjithaya, JNC/ISER). DBT, 2017 – 2020
3. Endocytosis during Plasmodium liver stage (with Sathish Misra, CDRI, Lucknow). SERB, 2018 – 2020
4. Quantitative analysis of host determinants of intracellular mycobacterial survival. DST-Max Planck Partner Group, 2015–2020

Marcus Taylor
AXA Fellowship, 1.12.12 – 30.09.2017

Mukund Thattai (Coordinator)
(Other investigators: Shachi Gosavi, Sandeep Krishna, Madan Rao, Shashi Thutupalli) Simons Centre for the Study of Living Machines, Simons Foundation, USA, 01.08.2013 – 31.07.2018 (Phase I), 01.08.2018 – 31.07.2023 (Phase II)

Vatsala Thirunmalai
1. Investigating the role of gap junctions at an identified glutamatergic synapse in a developing vertebrate. Department of Biotechnology, 2013 – 2018
2. Elucidating the functions of an autism-related gene in nervous system development. SERB, DST, 2016 – 2019

Shashi Thutupalli
1. Self-organization of cellular form and function, Max Planck Partner Group. since April 2017, for 3+2 years
2. (with Shachi Gosavi, Sandeep Krishna, Madan Rao, Mukund Thattai) Simons Center for the Study of Living Machines, Simons Foundation Targeted Grant, July 2013, for 5 years

Radhika Venkatesan
1. Ramanujan Re-entry Fellowship, DST-SERB, since December 2015 (for 5 years)
2. Chemical Ecology of plant-insect interactions. DST-Max Planck Partner group program grant, June 2017 (for 3 years)
3. Understanding allocation patterns of plant defence responses and insect adaptation mechanisms. Early Career Award from DST-SERB, since Sep 2016 (for 3 years)
4. Chemical Ecology in North East Region (NER) of India: A collaborative programme linking NER and Bangalore researchers. DBT NER grant, since March 2015 (for 5 years)

Daniel Weatherill
Using CREB overexpression to track systems consolidation of an allocated memory trace. ECF, Wellcome Trust-Department of Biotechnology India Alliance, 01.08.2012 – 31.07.2017

Gnaneshwar Yadav
Unravelling the role played by neuronal gap junction protein Connexin 35 (Cx35) in zebrafish. SERB, 30.11.2015 – 29.11.2018
Measuring cell-cycle related DNA damage responses on a cell-by-cell basis from microscopic image analysis

A microscopy-based assay was developed for determining cell cycle stages over large cell numbers. Upon DNA damage, γH2A.X induction was correlated to nuclear enrichment of p53 on a cell-by-cell basis and in a cell cycle dependent manner. Further imaging-based cell cycle analysis was combined with single molecule tumour suppressor P53 mRNA detection and immunofluorescence for p53 protein in the same cells. An intriguing suppression of P53 transcription was found, across different stages of the cell cycle, with DNA damage. This method can be used to study cell-cycle-dependent DDR in cultured cells without the need for synchronization. [Shivnarayan Dhuppar, Aprotim Mazumder]

Single molecule RNA Fluorescence in situ Hybridization to monitor differential expression of EGFR target genes in primary Drosophila tissue

Single molecule Fluorescence in situ Hybridization (smFISH) for mRNA provides a powerful quantitative handle on gene expression. While the method has been widely applied in cells in culture, applications to primary tissue samples remain fewer, and often use involved cryosectioning. A modified method of smFISH applicable on various primary whole-mount tissues from the fruit fly Drosophila melanogaster was developed. This method is being currently used to investigate the links between EGFR signalling and cell proliferation. [Nikhita Pasnuri, Aprotim Mazumder]

Chromatin compaction changes in response to DNA damage monitored by fluorescence anisotropy

Previously, it was described how fluorescence anisotropy can be used to monitor chromatin compaction states.
Cellular responses to mitochondrial stress in neuronal health and diseases

To understand the mechanism of mitochondrial quality control and its implications in neuronal health and diseases, a small scale genetic screen was performed in the model organism Drosophila melanogaster. The altered mitochondrial abundance was tested, along with the levels of mitochondrial fusion protein Marf in a set of loss-of-function mutants. Through this screen, it was identified that increased mitochondrial biogenesis resulted due to mutations in lrpprc2. An important thing to be noted is that lrppc2 is known to be essential for mitochondrial mtRNA stability. Further, fused mitochondrial phenotype was observed with concomitant degradation of Marf in lrpprc2 mutants. It was found that Pink, Parkin, and Bendless are essential for the degradation of Marf following the mitochondrial fusion to avoid mitochondrial hyperfusion. It is to be noted that human homologs of lrpprc2, pink and parkin genes have been implicated in neurodegenerative diseases. Increased mitochondrial biogenesis and Marf degradation in lrpprc2 appears to be a protective mechanism. [Deepa Balasubramaniam, Arka P. Das, Tanya Singh, Neha Singhal, Manish Jaiswal]

Mechanobiology of cell competition

It remains to be understood how mechanical cues influence the initial stages of cancer development and tumour suppression. It was shown that the stiffening of extracellular matrix (ECM) inhibited the cell competition-mediated removal of Ras-oncogene expressing cells, thus abrogating the primary epithelial defence against cancer. Stiff ECM inhibited the kinetics of the competition-mediated removal of the RasV12-expressing cells. RasV12 expressing cells appeared to be extruding much faster when the competition took place over a 4 kPa ECM than over a 23 kPa or 90 kPa ECM. Upon performing monolayer stress microscopy (MSM), it was found that the homeostatic level of the monolayer stress was higher in the wild-type population than in RasV12 expressing population. Biophysical characterization using Bayesian inverse stress microscopy (BISM) at the collective level revealed that cell competition gave rise to local compressive stress within the loser population. Together, these results showed the implications of forces in cancer biology, especially at the tumour suppression phase. [P. Phani Shilpa, Sanjay Karki, Tamal Das]

Nanoscale analysis of synapses

The localization, transport of mRNA to synapses in neurons of the brain was investigated. Super-resolution microscopy tools were developed to investigate the composition of glutamate receptor ion-channels at ribbon synapses of auditory hair cells with the goal of understanding deafness induced structural rearrangements in these proteins. [Adish Dani]

Comparison of a STORM image of single ribbon synapse of the inner ear hair cell, with previously published EM image.

Stoichiometry and dynamics of calcium channels

A novel flexible stoichiometry of calcium ion channel subunits on the plasma membrane was discovered. Insights were gained on how these stoichiometries affect channel function. [Adish Dani]

Molecular Immunology and Cell Signalling

The origin and outcome of cell surface receptor induced ion flux in the signal transmission, gene expression and function of white blood cells, called T cells, is being investigated. Genetic errors in proteins involved in the calcium and magnesium flux inside T cells have been associated with primary immunodeficiencies and cancers in human and mice. In
particular, using a multi-disciplinary approach, this work is dissecting the novel and previously unsuspected direct regulation of T cell receptor induced ion flux and signal transmission by SNARE family, a group of proteins thought to be solely involved intracellular trafficking of protein cargo, thus far. Therefore, these studies hold the promise of obtaining paradigm shifting insights into T cell ion flux and moonlighting by SNARE family proteins in the regulation of immune response and cancer progression. [Monika Vig]

Role of cell-death in growing microbial colony

The occurrence of cell-death is an integral phenomenon of any developing multicellular community. Using both, mathematical and agent-based computer simulation modelings, the role of cell-death in a growing colony was investigated. Results show that cell-death can enhance and facilitate branch formation in a growing front. [Pushpita Ghosh and Herbert Levine]

Auto-chemotactic pattern formation in self-propelling bacteria

Bacteria, while forming biofilm-like multicellular complex organization, secrete chemotactic signaling molecules along with various extracellular polymeric substances. These secreted substances, in some cases, can attract or repel cells in the colony. To understand the spatial organization of reproducing bacteria in presence of possible chemo-attractive or chemo-repulsive interaction, a continuum model was invoked using reaction-drift-diffusion framework. The influence of logistic growth on chemotactic pattern formation was investigated. [Mrinmoy Mukherjee and Pushpita Ghosh]

Biological Chemistry and Molecular Biophysics

Structural characterization of α-synuclein oligomers

α-synuclein (α-Syn) aggregation into oligomers and fibrils is associated with Parkinson’s disease (PD) pathogenesis. Although the relative role of oligomers versus fibrils in neuronal cell death in PD is not known, recent studies suggest the oligomers are proximate neurotoxin causing the disease. In this study, it was shown that incubation of high concentration of α-Syn in a physiological buffer converts the monomers into a gel state. Structural characterization of the gel revealed simultaneous co-existence of monomers, oligomers and fibrils. Solid-state NMR study of oligomers reveals a structurally heterogeneous population comprising of α-helical and β-sheet rich oligomers while the x-ray diffraction patterns of fibrils indicates cross-β motif morphology. Given the recent evidences of gel-like state of protein aggregation associated with neurodegenerative diseases, the gel-state of α-Syn in this study represents a mechanistic and structural model for in vivo toxicity of α-Syn in PD. (Saayak Halder, Samir Maji [IIT Powai], Vipin Agarwal)
Understanding Protein Conformational Dynamics

T4 lysozyme (T4L) cavity mutants interconvert between compact conformations on the millisecond (ms) timescale. Although structures of the two compact conformers are available, the mechanistic details are still not available. By studying the interconversion process using CPMG NMR experiments performed as a function of viscosity, it was determined that interactions with water activate the molecules so that they can surmount the activation barrier. [Anusha B. Gopalan, Pramodh Vallurupalli]

New multiquantum (MQ) experiments to study protein conformational dynamics

Protein conformational dynamics occurring on the ms timescale are routinely characterised using CPMG type experiments. However, these experiments cannot be used to study faster process. The double and triple quantum transitions in methyl groups were exploited to investigate the process where the minor state lifetime is just ~50 μs. [Anusha B. Gopalan, Pramodh Vallurupalli]

Ligand binding to solvent inaccessible cavities in proteins

Ligands binding sites in protein molecules can be solvent inaccessible, these include oxygen binding to the heme group in Hemoglobin. Similarly, hydrophobic molecules like benzene bind a solvent inaccessible cavity in T4L cavity mutants rapidly. Using MD simulations, it was shown that tunnels to the cavity from the surface are transiently formed by the displacement of helices in the C-terminal domain of the protein.

The fact that paths are created without any distortion in secondary structure shows that activation barrier is modest and hence ligands can bind rapidly. [N. Ahalawat, Subhendu Pandit, I.E. Kay (University of Toronto), Jagannath Mondal, Pramodh Vallurupalli]

Reconstructing the spectrum of the ‘invisible’ minor states of proteins.
**Atomistic insights into structural differences among isoforms of Apolipoprotein E**

Among various isoforms of Apolipoprotein E (ApoE), the E4 isoform (ApoE4) is considered to be the strongest risk factor for Alzheimer's disease, while E3 isoform (ApoE3) is neutral to the disease. Interestingly, the sequence of ApoE4 differs from its wild type ApoE3 by a single amino acid C112R in the 299 amino acid long sequences. Hence the puzzle remains: how a single-amino-acid difference between ApoE3 and ApoE4 sequence can give rise to structural dissimilarities between the two isoforms, which can potentially lead to functional differences with significant pathological consequences. The major obstacle in addressing this question has been the lack of a three-dimensional atomistic structure of ApoE4 till date. This issue was resolved by computationally modelling plausible atomistic three-dimensional structure of ApoE4. Microsecond-long atomistic simulations elucidated key structural differences between monomeric ApoE3 and ApoE4, which renders ApoE4 thermodynamically less stable, less structured and topologically less rigid compared to ApoE3. [Angana Ray, Navjeet Ahalawat, Jagannath Mondal]

**Insights on mechanical stability of a protein under force at a single molecule level**

Single molecule force spectroscopy is a useful technique for investigating mechanically induced protein unfolding and refolding under reduced forces by monitoring the end-to-end distance of the protein. The data is often interpreted via a two-state model based on the assumption that the end-to-end distance alone is a good reaction coordinate and the thermodynamic behaviour is then ascribed to the free energy as a function of this one reaction coordinate. In this study, the free energy surface (PMF) of GB1 protein was determined from atomistic simulations in explicit solvent under different applied forces as a function of two collective variables (the end-to-end-distance, and the fraction of native contacts). Brownian dynamics simulations on the smoothed free energy surface showed that the protein visits a metastable molten globule state and is thus a three state folder, not the two state folder inferred using the end-to-end distance as the sole reaction coordinate. This study lends support to recent experiments that suggest that GB1 is not a two-state folder. [R. Berkovich (Ben-Gurion University), Jagannath Mondal and B. J. Berne (Columbia University)]

**Kinetic Mechanisms of exit of an anticancer drug dasatinib from the receptor**

Obtaining atomistic resolution of drug unbinding from a protein is a much sought-after experimental and computational challenge. The unbinding dynamics of the anticancer drug dasatinib from c-Src kinase in full atomistic resolution was reported using enhanced sampling molecular dynamics simulations. Multiple unbinding trajectories were obtained and a residence time in agreement with experiments was determined. Coupled protein-water movement through multiple metastable intermediates was observed. The water molecules formed a hydrogen bond bridge, elongating a specific, evolutionarily preserved salt bridge and enabling conformation changes essential to ligand unbinding. This water insertion in the salt bridge acted as a molecular switch that controls unbinding. These findings provided a mechanistic rationale for why it might be difficult to engineer drugs targeting certain specific c-Src kinase conformations to have longer residence times. [P.Tiwary, Jagannath Mondal and B. J. Berne (Columbia University)]

**Solid-state NMR spectroscopy of amyloid fibrils**

\(\beta\) peptide continues to be an interesting model for investigating different aspects of amyloid aggregation. Clear evidence was obtained regarding the role of certain structural markers when these transit from monomers to fibrils through oligomers from previous studies by the group. Studies were initiated to understand the binding of these peptides with cell membranes. Initial solid-state NMR experiments suggest a rupture of one of the stable contacts upon binding with the membranes. A similar pattern was also found at the salt-bridge region, although that needs to be quantified. Such studies may lead to a further understanding of the role of these peptides in toxicity. Detailed solid-state NMR and fluorescence correlation spectroscopy studies were carried out on IAPP, the peptide responsible for type-II diabetes. [P. K. Madhu, Kaustubh Mote, Sudipta Maiti (TIFR Mumbai)]
Secondary structure changes from membrane bound $A\beta$ oligomer to fibrils.

Structural Biology of Actins

In a bid to understand the fibrillization of actins and their regulation a number of proteins, the initial solution NMR experiments were expressed, purified and done. [Kaustubh Mote]

Structural Biology of Membrane proteins

The components of Mitochondrial Pyruvate Carrier Complex, a vital protein involved in the regulation of the pyruvate flux into mitochondria, were successfully cloned, over-expressed and purified. To address questions in the area of active transport across membranes, the SemiSWEET transporter from bacteria was cloned. [Kaustubh Mote]

Underpinning the mechanistic action of short-chain antimicrobial $\beta$-peptides with membrane

Amphiphilic $\beta$-peptides are short-chain, rigid synthetic oligomers of $\beta$-amino acids which serve as alternatives of natural antimicrobial peptides. It was addressed whether the distinct molecular architecture of these short-chain and rigid $\beta$-peptides undergoes a distinct mechanistic action with membrane bilayer. Multi microsecond computer simulations and free-energy calculations were performed which deciphered the interaction of membrane with antimicrobial 10-residue $\beta$-peptides at diverse range concentrations. Using specifically developed parameters for $\beta$-peptides, this study reveals spontaneous insertion of $\beta$-peptides in the membrane interface at a low concentration and identifies partial water leakage in the membrane at a high concentration, without affecting the $\beta$-peptides' secondary structure.[Pushpita Ghosh, Jagannath Mondal, Xiao Zhu (Purdue University)]

Chemical synthesis of novel natural/non-natural protein inhibitors that would interfere with the invasion of human red blood cells by malaria parasite

A new method for the facile cleavage of chemically synthesized peptides from solid support was recently developed. Analogs of malaria parasite proteins were chemically modified and rationally designed using methods developed in the laboratory. These have the potential to prevent formation of tight junction between parasite and erythrocyte, mediated by apical membrane antigen-1 (AMA1) and rhoptry neck protein (RON2), before the process of invasion takes place. These rationally designed protein molecules have the potential to significantly impact the elimination of malaria transmission worldwide. [Puneet Dubey, Sameer Singh, Jamsad Mannurbdikayil, Suman Sinha, Anamika Biswas, Abhishek Kar, Kalyaneshwar Mandal]

Building a super-resolution optical microscope

A super resolution fluorescence microscope was built to monitor growth of amyloid fibrils at single particle level. The data reveal that amyloid growth is highly heterogeneous, and follows a stop and go model. Amyloid fibrils form extensive network via cross-over between the fibrils rather than due to branching. [Kanchan Garai]

Characterization of role of chaperone Hsp70 on aggregation of amylin

It was found that Hsp70 inhibits amyloid aggregation of amylin even in substoichiometric concentrations. Furthermore, Hsp70 interacts with the oligomers but not with the monomers of amylin. [Kanchan Garai]
Characterization of role of apoE on aggregation of Amyloid beta

It was found that apoE interacts with amyloid beta with high affinity. Furthermore, apoE contains multiple independent interaction sites for amyloid beta peptide. [Kanchan Garai]

Fluid Dynamics

Topology of two dimensional flows of dust and gas

Direct numerical simulations (DNS) of passive heavy inertial particles (dust) in homogeneous and isotropic two-dimensional turbulent flows (gas) were performed for a range of Stokes number, St< 1. It was solved for the particles using both a Lagrangian and an Eulerian approach (with a shock-capturing scheme). In the latter, the particles are described by a dust-density field and a dust-velocity field. Using inertial particle velocity gradients and the corresponding flow topology, the density weighted joint distribution shows that converging saddle structures are most probable. [Dhrubaditya Mitra (Nordita- KTH Royal Institute of Technology and Stockholm University), Rahul Pandit (IISc Bangalore), Debarghya Banerjee (Huygens Laboratory), Akshay Bhatnagar (Nordita- KTH Royal Institute of Technology and Stockholm University), Marc Brachet (PSL Research University, Sorbonne Universités), Anupam Gupta (Université de Toulouse), Nairita Pal (IISc Bangalore), Debarghya Banerjee (Huygens Laboratory), Akshay Bhatnagar (Nordita- KTH Royal Institute of Technology and Stockholm University), Marc Brachet (PSL Research University, Sorbonne Universités), Anupam Gupta (Université de Toulouse), Rahul Pandit (IISc Bangalore), Nairita Pal (IISc Bangalore), Soubhik Sarkar, Ram Gopal, M Krishnamurthy]

Laser Physics

Studies on laser-cluster interaction dynamics

Non-linear absorption of intense (>10^15W/cm2), sub-ps pulses by Ar and N2 clusters were observed. When comparatively studied as a function of the pulse width, it allowed distinguishing of field driven ionisation contribution from collective effects. The large difference in absorption trends between Ar and N2 as a function of pulse widths indicated different mechanisms being in play. Small N2 cluster systems provide an ideal model system wherein field ionization dominates, whereas Ar clusters show resonance absorption for long pulses. Till date, it was possible to “switch off” different phenomena which accompany ionisation of clusters only in theory and simulations. The same was demonstrated experimentally, specifically to isolate collective and non-collective effects. The results also indicate that schemes that presume non-uniform electron density wherein different regions of clusters can come into the resonance with the light fields at different times may not always be appropriate. [Angana Mondal, S. V. Rahul, Deobrata Rajak, Ram Gopal, M Krishnamurthy]

Intense laser plasmas from matter on mesoscopic scales- Liquid drop experiments

Generation of energetic electrons, as high as 6MeV, has been observed from laser matter interaction in methanol droplets. Two distinct energy regimes, one ranging from 200keV-1MeV and other from 1MeV-6MeV, have been identified. The electron temperatures are found to be 200keV and 900keV respectively. Angular distribution measurements show that the electrons are confined in the laser polarization plane and are emitted mostly at ± 50° with respect to the laser backward direction. Dependences on intensity and pulse-width have also been studied. Single and double pulse Z-scans of the focussed laser beam on the droplet indicate thermalization effects in presence of a pre-pulse. Protons with energy as high as 560keV have also been detected. X-rays, till 150keV, are found to be emitted directly from the drop. These X-rays have been used to obtain high resolution ~ 50um, images of metallic and biological samples. [Angana Mondal, S. V. Rahul, Deobrata Rajak, Ram Gopal, M Krishnamurthy]

Collaborative experiments in femtosecond dynamics in molecules

A velocity map imaging spectrometer for ions was set up. The dissociative ionization of O2 and CH3I at intensities of 1013-1014 W/cm2 of 30 fs laser pulses was studied. The energy and angle resolved ion fragments from O2 when studied as a function of the incident intensity indicated the role of excited state polarizabilities of the ions and the resultant rotation of the ion under the influence of the electric field post ionization. Further analysis is underway to quantify
these mechanisms. In a recently concluded experiment, the dissociation of CH3I, as a function of pulse width of the laser, was studied. The motivation is to look at possible internal conversion events wherein charge transfers from the CH3 to I post ionization. [D Rajak, Ram Gopal, Arnab Sen (IISER Pune), Vandana Sharma (IIT Hyderabad), M. Krishnamurthy]

A methanol drop instantly heated to a billion kelvin emits light (visible and x-rays) like the sun.

Resource generation and innovation activities

In a novel initiative, TIFR Hyderabad and the Central Laser Facility, Rutherford Appleton Lab (RAL), Oxford UK have entered into a collaboration to develop the control systems for next generation Petawatt Laser and particle acceleration systems. The new Innovation Centre was set up with the induction of 5 engineers with software and electronic engineering backgrounds funded by RAL. With support and supervision from members of the Laser Lab and technology and training support from RAL, it envisaged to result in a full self-sustained control system which would be of interest to laser companies and research institutes worldwide. [M. Krishnamurthy]

Material Sciences

Thin film growth of superconducting Magnesium diboride (MgB2)

MgB2 is a compound superconductor with the highest transition temperature among other BCS superconductors. Superconducting thin films of this compound were grown using a single target sputtering source. Further film optimization and device fabrication is currently underway. [Karthik V. Raman]

Epitaxial growth of topological insulator, Bismuth selenide

Epitaxial growth of Bismuth selenide was possible in our custom designed molecular beam epitaxy system. Complete structural characterization confirmed very high quality of the films grown. Proximity effect with a ferromagnetic insulator such as Europium sulphide is underway. [Karthik V. Raman]

Atomic layers based catalysts

Though graphene technology has reached in to technology readiness level 9 (TRL9), pristine layers are still inactive towards certain important catalytic reactions such as hydrogen evolution reaction (HER), oxygen reduction reaction (ORR), and oxygen evolution reaction (OER). Hydrogen is identified as a futuristic energy resource due to its high energy density, and water splitting as a greener route towards its production. Research efforts were directed at the development of disorderly and orderly arranged atomic heterostructures of graphene, MoS2, and hexagonal boron nitride (hBN), and their activity studies towards various catalytic reactions.

Image showing the assembly of shear exfoliated single layer graphene (SEG) and hBN on glassy carbon electrode (GCE).

A high resolution of transmission electron microscopic image of the same showing two types of atomically thin domains - graphene and hBN.
It was found that such vertical interfaces of two different atomic layers can make the structure active towards HER, where the individual layers are not active at all. A mechanistic picture in to this observed mechanism is given using density functional theory based calculations and molecular dynamics based studies. This heterostructure activity study was extended to other structures such graphene/MoS2, too, where they were also found to be active towards photocatalysis. Further, stacking sequence dependent catalytic activity of layers is also disclosed in these studies. This is a novel aspect of such materials, which was not found in other catalysts and/or reported before on atomic layers.

Ion transport membranes for pure water electrolysis

New type of proton (H+) transport membrane cum separator were designed and developed which was found to be working even in pure water electrolysis. Economically inexpensive, proton transporting solid state polymer membrane (HPEOP) was developed using perchloric acid (HClO4) as proton source with poly(ethylene oxide) (PEO) and polydimethylsiloxane blend as hosting structure. Room temperature (25 oC) low humidity ionic conductivity of HPEOP is found to be 0.0032 S/cm, and lowering the melting temperature of PEO through HClO4 ‘salting in’ was found to have considerable effect in enhancing the conductivity of solid electrolytes, while this also modifies the microstructure and mechanical strength of the membrane. Water electrolysis cells were constructed with both pure and protonated water using both HPEOP and Nafion separators, and studies showed the possibilities of highly efficient low cost water electrolysis and fuel cells devoid of expensive Nafion membranes.

Chemical vapor deposition assisted synthesis of atomic layers for devices

High quality atomic layers can be developed using chemical vapor or physical vapor deposition assisted methods. Efforts were underway to develop such high quality crystals of graphene, MoS2, and doped graphenes such as fluorographene (oxide) and boron and/or nitrogen doped graphene. Single step, catalyst free, wafer-scale synthesis of fluorographene oxide (FGO) ultra-thin films synthesis by physical vapour deposition was reported. This FGO, possessing 7% fluorine content, comprises a few nanometer domains of sp2-sp3 carbon with high thermal stability. It was shown that FGO can be utilized as an active hetero-layer on a few-layer MoS2 field effect transistor (FET), significantly improving the performance of MoS2 optoelectronic devices with an extended spectral response towards the near infrared and responsivity of up to 6A/W. The FGO-MoS2 band alignment as derived from the measured work function of FGO indicated a photoconductive gain mechanism with a fast transit time of holes mediated by FGO quasi-continuous defect states.
Nuclear Magnetic Resonance Spectroscopy

Decoupling schemes in solid state NMR

Spin decoupling is essential in solid-state NMR to improve the resolution and sensitivity of the spectra of both rare and abundant spins. In the former case, such as 13C and 15N, heteronuclear dipolar decoupling is used whilst in the latter, such as 1H, homonuclear dipolar decoupling is used. Both these methods were combined in magic-angle spinning (MAS) solid-state NMR experiments. This is important in the observation of high-resolution 1H spectra in samples that are uniformly labelled with either 13C or 15N or both. The homonuclear decoupling scheme was applied to the 1H channel and heteronuclear decoupling on the 13C or 15N channel. Optimal strategies were found to minimise the interference effects between these two time-dependent processes and the MAS. This was the main reason why various attempts in this direction failed in the past and our experiments were able to circumvent this by knowledge of the theory of the interference effects and also with the application of the much robust rotor-synchronised rCW heteronuclear decoupling scheme developed in our group. This is expected to be useful in the study of biomolecular systems at high MAS and low radiofrequency (RF) amplitude regimes where proton detection can be useful but at the same time one has to encounter the isotopically labelled rare spins. [P. K. Madhu, K. Mote]

Towards spin exchange optical pumping of Xe

Spin-exchange optical pumping was set up. This was aimed at hyperpolarising NMR signals, primarily observing NMR signals from noble gases such as Xenon. The aim is mainly investigations in the area of low-field NMR and magnetometry. In this direction, a rubidium magnetometer for the detection of NMR signals was built. [G. Rajalakshmi, Vineeth Francis, P. K. Madhu]

Recoupling pulse schemes and strategies

The standard rotational-echo double resonance (REDOR) experiment used in solid-state NMR has proven to be one of the most useful and robust schemes in distance measurements. Robust variants of this scheme were introduced to measure strong one-bond dipolar couplings with a high precision by shifting the pulses in a way that can be quantified with average Hamiltonian theory and numerical simulations. The proposed methods allow scaling down of the dipolar coupling in the full range of 0-1. The results are also free of any orientational dependence of the crystallites in the sample that plagued similar attempts in the past. The scaling factor is independent of the RF and MAS frequency and can be applied over a wide range of MAS frequencies. [Mukul Jain, G. Rajalakshmi, Kaustubh Mote, Vipin Agarwal, Matthias Ernst (ETH, Zurich), P. K. Madhu]

Hydro-dynamics of particle wall interactions

For the first time, it was experimentally established that, as opposed to the common belief of lubrication theory, there is solid-on-solid contact during sphere-wall collision in a viscous fluid. [Sumit Kumar Birwa (ICTS]
Polarisation rotation angle as a function of longitudinal magnetic field, with images profile change for various rotation angles

Measuring quantitative proton-proton distances in fully protonated solids

The experiments to quantitatively measure proton-proton distances still remain elusive mainly due to the presence of strong and multiple proton-proton dipolar couplings. In this project, a new MAS solid-state NMR method was proposed to selectively measure proton distances in fully protonated samples. The proposed novel sequence generates a homonuclear double quantum dipolar Hamiltonian that is additionally modulated by the sum of the chemical shifts. At certain conditions the chemical shifts modulation can be eliminated which in turn leads to selective recoupling of the dipolar Hamiltonian. It was shown in a small molecule system that quantitative 1H-1H distances of up to few angstroms can be measured despite the presence of other strongly coupled protons. The experiment can also be used for selective first-order proton-proton polarization transfer in macromolecules like proteins. Major applications of this methodology would be in structural characterization of pharmaceutical polymorphs and biomolecules. [Sreejith Kurussi, Yusuke Nishiyama (Jeol, Yokohama Japan), Vipin Agarwal]

Polarization transfer buildup curves a) H7 → H6 & H8 b) H5 → H6 & H8 using SERP recoupling. The red and black strip show the confidence interval for fitting of the data. The inset highlights the average percentage deviation in intensity per point between experimental and simulated data c) Structure of Histidine and corresponding distances d) Selective HN → HN transfer in MLF tripeptide and e) Selective HN → Hα transfer in Ubiquitin. Positive contours are depicted in green while negative contours are depicted in brown.
Theoretical description of BASS-SD

In the recent past, the BASS-SD experiment (J. Phys. Chem. Lett., 8, 2399-2405 (2017)) was proposed to obtain long-range selective 1H-1H contacts on the order of 5-6 Å despite the presence of other protons at shorter distances in fully protonated proteins. The BASS-SD experiment is particularly useful in providing 1H-1H structural restraints for structure determination. This year, a theoretical model based on bimodal Floquet theory was proposed to explain these results. The theoretical model can predict the behaviour of magnetization transfer in a homogenously coupled spin system under conditions of weak rf irradiation and ultrafast MAS frequencies. [P.K. Madhu, Vipin Agarwal]

Through bond correlation spectroscopy (TOBSY)

Through bond J-coupling based experiments in solid-state NMR spectroscopy are challenging because the J couplings are typically much smaller than the dipolar couplings. This often leads to a lower transfer efficiency compared to dipolar-based sequences. One of the reasons for the low transfer efficiency is second-order cross terms involving the strong heteronuclear dipolar couplings. In this project, it was shown that by employing a symmetry-based C9 sequence, which was carefully selected to suppress second-order terms, efficient polarization transfers of up to 80% can be achieved without decoupling on fully protonated two-spin model systems at a MAS frequency of 55.5 kHz with rf-field amplitudes of about 25 kHz. In addition, the effects of rf inhomogeneity and crystallites selection due to the polarization preparation method on the TOBSY transfer efficiency was analyzed. It was also demonstrated that on small model substances as well as on the protein ubiquitin (side-chains deutered, amides fully protonated) that C91/39 and C91/48 are efficient and practical TOBSY sequences, at experimental conditions ranging from proton Larmor frequencies of 400 to 850 MHz and MAS frequencies ranging from 55.5 to 111.1 kHz. [Beat Meier and Matthias Ernst (ETH Zurich, Vipin Agarwal)]

Synthetic Chemistry

Preparation of a pentagonal bipyramidal lanthanide complex

The design of the complex was made with the objective of obtaining a weak equatorial crystal field and strong axial field. The challenge in this design was two-fold. One, lanthanide ions prefer large coordination numbers and restricting their coordination to numbers below eight is tricky. Second, the ligand design should be such that a pentagonal bipyramidal geometry is naturally imposed in the resulting complex. These two challenges were met and the complexes (Et3NH)[(H2L)LnIIICl2] (where H4L = 2,6-diacetylpyridine bis-salicylhydrazone and Ln = Tb (1), Dy (2), and Y0.94Dy0.06 (3) could be prepared and characterized. Among these 2 and 3 were shown to be single-molecule magnets. (A. K. Bar, P. Kalita, J. P. Sutter, V. Chandrasekhar)
Multiple bonded compounds of heavier main group elements

The synthesis of 2-hydroiminosilane and its addition reaction with water was reported. The reactivity of bulky substituted diphosphene, a phosphorus-phosphorus double bonded compound, was enhanced by the reversible coordination of N-heterocyclic carbene with respect to hydrolysis and hydrogenation reactions. [Anukul Jana, Debabrata Dhara, Debdeep Mandal, Avijit Maity, Ramakrishnan Suriya Narayanan]

Low-Valent Main Group Compounds

Electron-rich alkenes considering peralkyl substituted triazaalkenes motif were synthesized. These oxidized reversibly, stepwise and were able to isolate corresponding radical cations and dications of it. The mono and di-coordinated germanium(0) which act as a four electron donor was disclosed. [Anukul Jana, Debdeep Mandal, Ramapada Dolai, Debabrata Dhara, Avijit Maity, Ramakrishnan Suriya Narayanan]

Soft Matter

Characterising solid-solid transitions in colloids

A framework to segregate the roles of elastic and non-elastic deformations in the examination of real-space experiments of solid-solid transitions was presented. The Martensitic transformation of a body-centred-tetragonal (BCT) to a body-centred-orthorhombic (BCO) crystal structure has been studied in a model system of micron-scale ionic microgel colloids. Non-affine fluctuations, i.e., displacement fluctuations that do not arise from purely elastic (affine) deformations, are detected in particle configurations acquired from the experiment. Tracking these fluctuations serves as a highly sensitive tool in signaling the onset of the Martensitic transition and precisely locating particle rearrangements occurring at length scales of a few particle diameters. Particle rearrangements associated with non-affine displacement modes become increasingly favorable during the transformation process. The nature of the displacement fluctuation modes that govern the transformation are shown to be different from those predominant in an equilibrium crystal. It was shown that BCO crystallites formed through shear may, remarkably, co-exist with those resulting from local rearrangements within the same sample. [Saswati Ganguly, Priti S. Mohanty (KIIT University, Lund University), Peter Schurtenberger (Lund University), Surajit Sengupta and Anand Yethiraj (Memorial University, St. John’s Newfoundland Labrador)]

Dynamical, feedback controlled laser traps for stabilising colloidal crystals of any given symmetry

It was shown that dynamic, feed-back controlled optical traps, whose positions depend on the instantaneous local configuration of particles in a predetermined way, can stabilise colloidal particles in finite lattices of any given symmetry. Unlike in a static template, the crystal so formed is invariant under uniform translations and retains all possible zero energy modes. This was demonstrated in silico by stabilising the unstable two-dimensional square lattice in a model soft solid with isotropic interactions. [Pankaj Popli, Saswati Ganguly and Surajit Sengupta]

Theoretical Physics

Spreading of non-motile bacterial colonies on a hard agar plate

The spreading of a non-motile bacterial colony on a hard agar plate was studied using agent-based and continuum models. It was shown that the spreading dynamics depends on the initial nutrient concentration, the motility, and the inherent demographic noise. Population fluctuations are inherent in an agent-based model, whereas for the continuum model we model them by using a stochastic Langevin equation. It was shown that the intrinsic population fluctuations coupled with nonlinear diffusivity lead to a transition from a diffusion limited aggregation type of...
morphology to an Eden-like morphology on decreasing the initial nutrient concentration. [Navdeep Rana, Pushpita Ghosh, Prasad Perlekar]

A novel method to study growth of amorphous order in glass-forming liquids

Existence and growth of amorphous order in supercooled liquids approaching glass transition is a subject of intense research. Even after decades of research, there is still no clear consensus on the molecular mechanisms that lead to a rapid slowing down of liquid dynamics approaching this putative transition. The existence of a correlation length associated with amorphous order has recently been postulated and this has been estimated using multi-point correlation functions, which cannot be calculated easily in experiments. Thus the study of growing amorphous order remains mostly restricted to systems like colloidal glasses and simulations of model glass-forming liquids. An experimentally realizable yet simple correlation function was proposed to study the growth of amorphous order. The validity of this approach was then demonstrated for a few well-studied model supercooled liquids and the results obtained were consistent with other conventional methods. [Rajeshkhar Das, Saurish Chakrabarty (ICTS Bangalore), Smarajit Karmakar]

Block analysis for the calculation of dynamic and static length scales in glass-forming liquids

Block analysis is an efficient method of performing finite-size scaling for obtaining the length scale of dynamic heterogeneity and the point-to-set length scale for generic glass-forming liquids. This method involves considering blocks of varying sizes embedded in a system of a fixed (large) size. The length scale associated with dynamic heterogeneity is obtained from a finite-size scaling analysis of the dependence of the four-point dynamic susceptibility on the block size. The block size dependence of the variance of the $\alpha$ relaxation time yields the static point-to-set length scale. The values of the obtained length scales agree quantitatively with those obtained from other conventional methods. This method provides an efficient experimental tool for studying the growth of length scales in systems such as colloidal glasses for which performing finite-size scaling by carrying out experiments for varying system sizes may not be feasible. [Saurish Chakrabarty, Indrajit Tah, Smarajit Karmakar, and Chandan Dasgupta (IISc Bangalore)]

Glass transition in supercooled liquids with medium range crystalline order

The origins of rapid dynamical slow-down in glass forming liquids in the growth of static length scales, possibly associated with identifiable structural ordering, is a much-debated issue. Growth of medium range crystalline order (MRCO) has been observed in various model systems to be associated with glassy behaviour. Such observations raise the question about the eventual state reached by a glass former, if allowed to relax for sufficiently long times. Is a slowly growing crystalline order responsible for slow dynamics? Are the molecular mechanisms for glass transition in liquids with and without medium range crystalline order the same? If yes, glass formers with MRCO provide a paradigm for understanding glassy behaviour generically. If not, systems with MRCO form a new class of glass forming materials whose molecular mechanism for slow dynamics may be easier to understand in terms of growing crystalline order, and should be approached in that manner, even while they will not provide generic insights. In this study, extensive molecular dynamics simulations of a number of glass forming liquids in two dimensions were performed. It was shown that the static and dynamics of glasses with MRCO are different from other glass forming liquids with no predominant local order. An important issue regarding the so-called Point-to-set method for determining static length scales was resolved, it was demonstrated to be a robust, order agnostic, method for determining static correlation lengths in glass formers. [Indrajit Tah, S. Sengupta, S. Sastry, C. Dasgupta, Smarajit Karmakar]

Role of $\alpha$ and $\beta$ relaxations in collapsing dynamics of a polymer chain in supercooled glass-forming liquid

Understanding the effect of glassy dynamics on the stability of bio-macromolecules and investigating the underlying relaxation processes governing degradation processes of these macromolecules are of immense importance in the context of bio-preservation. The stability of a model polymer chain in a supercooled glass-forming liquid at different amount of supercooling was studied in order to understand how dynamics of supercooled liquids influence the collapse behavior of the polymer. Our systematic computer simulation studies find that apart from long time
relaxation processes (α relaxation), short time dynamics of the supercooled liquid, known as β relaxation plays an important role in controlling the stability of the model polymer. This is in agreement with some recent experimental findings. These observations are in stark contrast with the common belief that only long time relaxation processes are the sole player. Convincing evidence was found that suggest that one might need to review the vitrification hypothesis which postulates that α relaxations control the dynamics of biomolecules and thus α-relaxation time should be considered for choosing appropriate bio-preservatives. Our results may potentially lead to the understanding of primary factors in protein stabilization in the context of bio-preservation. [Mrimoy Mukherjee, Jagannath Mondal, and Smarajit Karmakar]

Possible universal relation between short time β-relaxation and long-time α-relaxation in glass-forming liquids

Relaxation processes in supercooled liquids are known to exhibit interesting as well as complex behavior. One of the hallmarks of this relaxation process observed in the measured auto correlation function is occurrence of multiple steps of relaxation. The shorter time relaxation is known as the β-relaxation which is believed to be due to the motion of particles in the cage formed by their neighbors. On the other hand, longer time relaxation, the α-relaxation is believed to be the main relaxation process in the liquids. The timescales of these two relaxations processes dramatically separate out with supercooling. In spite of decades of researches, it is still not clearly known how these relaxation processes are related to each other. It was shown that there is a possible universal relation between short time β-relaxation and the long-time α-relaxation. This relation is found to be quite robust across many different model systems. Finally it was shown that length scale obtained from the finite size scaling analysis of β timescale is same as that of length scale associated with the dynamic heterogeneity in both two and three dimensions. [Rajsekhar Das, Indrajit Tah, and Smarajit Karmakar]

Inductive and Deductive Modelling of Matter

Development of a big data repository of molecular and materials properties

The main components of a web-based data-mining platform has been implemented and hosted at TCIS. Molecular datasets from various sources has been injected into this repository. A new dataset of substituted poly-aromatic hydrocarbons with over several billion molecular structures and desirable opto-electronic properties has been generated at TIFR Hyderabad. [Raghunathan Ramakrishnan]

Science Education

Outreach was initiated in schools of the Telangana Social Welfare Residential Educational Institutions Society (TSWREIS). This sustained program of interaction included 73 mainly weekend visits to three neighbouring TSWREIS schools, each by an average of 4-5 volunteers from TCIS and University of Hyderabad. The volunteers conducted sessions with secondary and intermediate students aimed to support meaningful, laboratory-based science learning.

Low-cost paper microscopes called 'Foldscopes' were introduced in these schools on a pilot basis. A 'Meet a Scientist' program was conducted in face-to-face mode a local TSWREIS school and, in distance mode over the T-SAT Nipuna channel reaching remote schools in Telangana State. Interactions with TSWREIS are leading into an R&D project on curiosity and questioning.

Implementation of the 'Homi Bhabha Curriculum for Primary Science' (developed at HBCSE 15-20 years ago) was followed up with teachers in a few schools around the country. This community of progressive and innovative teachers was supported to document and share their experiences on the 'Small Science' website of HBCSE. [Jayashree Ramadas]

Research Scholars

Post-Doctoral Fellows

Junior / Senior Research Fellows
Jan 12, 2018), Debprata Rajak (since Aug 01, 2017), Dipanjana Saha (from Aug 24, 2017 to Dec 29, 2017), Dipanjana Saha (since Jan 01, 2018), Sameer Singh (since Sep 01, 2017), Bhaskar P. Soman (since Aug 01, 2017), Rakesh Kumar Y

Visiting Student/Project Assistant & Scientist/Project Associate/Short Term Visiting Fellows
Ramita Anand (since Jan 17, 2018), Abhirath Batra (from May 01, 2017 to Oct 31, 2017), Apeksha Madhukar Chipade (since Jan 01, 2018), Rajvi Chandranthan Dhimar (since Mar 26, 2018), Vandna Gokhroo (from Jan 05, 2018, Mar 04, 2018), Nikhil Jaisinghani (till Jun 30, 2017), Samvit Mohapatra (from May 09, 2017 to Nov 30, 2017), C. Neeraja (from Jan 02, 2018 to Feb 01, 2018), Adyasha Panda (since Mar 15, 2018), Swapneel A. Pathak (from Apr 03, 2017 to Jul 13, 2017), Subindev (since Jan 01, 2018)

Scientific/Technical staff

Administrative Staff

Project Staff

National and International involvement

Agarwal, Vipin
Member, National Magnetic Resonance Society of India

Chandrasekhar, V
1. Member, Editorial Board at Dalton Transactions (Published by Royal Society of Chemistry, Cambridge, UK)
2. Chairman, Project Advisory Committee of Inorganic and Physical Chemistry (Science and Engineering Research Board)

Krishnamurthy, M
2. Member, Editorial board, Scientific Reports (a Nature group Journal)
3. Secretary, Asian committee on ultra-intense laser (ACUIL), Technical program committee for the 2nd Asia Pacific conference held by Association of Asia Pacific Physical Societies, Division of Plasma Physics (2018)
4. Member, Swarnajathi Fellowship selection committee for the Physics section (2017)
5. Member, Expert committee for faculty recruitment and promotions in IIT Palakkad, NISER Bhubaneswar

Madhu, P. K.
1. Head, Research, finance, and administration, TCIS-TIFR Hyderabad
2. Fellow, National Academy of Science
3. Member secretary, TIFR H management board
4. Convener, MagRes academic advisory body (MRAAB) TIFR- Hyderabad
5. Member, Editorial board, Journal of Magnetic Resonance
6. Member, Editorial board, Solid State Nuclear Magnetic Resonance
7. Member, Editorial board, Journal of Biomolecular NMR
8. Member, Editorial board, Journal of Magnetic Resonance
9. Member, MAC, National Facility for High-Field NMR, TIFR
10. Member, Scientific programme committee, ISMAR at Quebec, Canada 2017
11. Member, ISMAR (International Society for Magnetic Resonance) council member
12. Member, National Magnetic Resonance Society of India
13. Member, LTF, TIFR Mumbai committee
14. Member, Various TIFR Hyderabad campus committees,
such as research committee, project implementation team, academic core committee, master plan committee, and detailed plan report committee.

**Mandal, Kalyaneshwar**
1. Member, American Peptide Society
2. Reviewer at Nature Communications

**Mazumder, Aprotim**
1. Reviewer, scientific articles in Cell Cycle, Biology Open, Current Science
2. Member, Subject Board of Biology, TIFR
3. Member, Subject Board of Chemistry, TIFR
4. Member, Academic Advisory Committee, TCIS
5. Chairperson, Institutional Biosafety Committee, TIFR Hyderabad

**Mondal, Jagannath**
1. Associate, Indian Academy of Sciences
2. Member, Biophysical Society
3. Member, American Physical Society
4. Member, American Chemical Society

**Narayanan, T. N.**
1. Member, Materials Research Society (2018)
2. Member, American chemical Society (July 2015 – July 2018)
3. Fellow, Royal Society of Chemistry
4. Associate, Indian Academy of Sciences (July 2015 – December 2018)
5. Guest Editor, Special issue of MRS Communications

**Visits**

**Agarwal, Vipin**
1. JSPS Invitational Fellow, Riken NMR Centre, Japan, October-November 2017
2. NMR meets Biology III Meeting, Leipzig, Sep 2017
3. 11th Alpine conference on solid-state NMR, Chamonix, France, September 2017

**Das, Tamal**
1. Stuttgart, Germany to strengthen the collaboration between our group and that of Prof. Joachim P. Spatz, Max Planck Institute of Medical Research, as a part of the Max Planck Partner Group award, 29 May – 11 June, 2017
2. Workshop on Physical and Systems Biology (WPSB), ICTS, Bengaluru, 12 June – 13 June, 2017

**Ghosh, Pusplita**
Indian Association for the Cultivation of Science and S. N. Bose National Centre for Basic Sciences, Kolkata, March 7 – 8, 2018

**Jana, Anukul**
Saarland University, Germany as a part of Research Group (2D Nanomaterials for Healthcare and Lab-on-a-Chip Devices)

**Madhu, P. K.**
1. EUROMAR meeting, Warsaw, Poland, July 2 – 6, 2017
2. University of Leipzig, Leipzig, Germany, Sep 3 – 8, 2017
3. University of Leipzig, Leipzig, Feb 24 – March 9, 2018
4. University of Bayreuth, Bayreuth, Germany, March 5 – 6, 2018

**Mandal, Kalyaneshwar**
1. Meditech Conclave, Conference on Advanced Medical Technologies for better Health Care, Hyderabad, June 2017
2. 24th Congress and General Assembly of the International Union of Crystallography, Hyderabad International Convention Centre, Hyderabad, Aug 2017

**Mazumder, Aprotim**
Visited institutes within India (Presidency University, University of Hyderabad)
Invited Talks

Agarwal, Vipin
1. Characterization of protein structures and transient species of α-Synuclein with MAS solid-state NMR techniques. Indo-German meeting on structural Biology NMR meets Biology III, University of Leipzig, Sep 2017
2. New developments of in fast MAS Solid-state NMR methodology of protein samples. Department of chemistry, Kyoto University, Japan, November 2017
3. Solid-state NMR methods to characterize transients’ species of protein and development of optimisation independent heteronuclear decoupling sequences for MAS solid-state NMR. Jeol Riken NMR Centre, Yokohama, Japan, November 2017

Chandralekha, V
NHC-stabilized Hydrosilamines and -Phosphasilenes. Indo-German Meeting ‘Elementary Reactions in Functional Materials: From Biophysics to Technological Applications’, University of Heidelberg, Germany, November 2017

Das, Tamal
1. Mechanobiology of Collective Cell Migration. 5th Heidelberg Forum for Young Life Scientists, Heidelberg, June, 2017
3. Mechanobiology of Collective Cell Migration. TCIS-UoH collaboration program, Dr. Reddy’s Institute of Life Sciences, Hyderabad, July, 2017
4. Mechanobiology of Collective Cell Dynamics: Migration and Competition. Soft and Active Matter Workshop, School of Physics, University of Hyderabad, Hyderabad, February, 2018

Garai, Kanchan
Visit to Washington University, St. Louis (gave a talk)

Rajalakshmi, G
1. Summer school on “Theory in NMR”, Windischleuba, Germany, 25 Feb – 4 Mar 2018
2. Visit to Xe NMR Lab of Prof. Senker at University of Bayreuth, Germany, 5 – 9 Mar 2018

Ramakrishnan, Raghunath
HiPC conference on high-performance computing, Ie Meridien, Jaipur, December, 2017

Ghosh, Pushpita
1. Spreading of non-motile bacteria on hard surface. ‘Nonequilibrium Dynamics: Diffusion, Populations and Aging’, TIFR-TCIS Hyderabad, June, 2017
2. Spatiotemporal ordering in growing bacterial colony. S. N. Bose National Centre for Basic Sciences, Kolkata, March, 2018

Jaiswal, Manish
1. Bidirectional synergism between fly and human genetics in health and diseases. Departmental seminar, Dr. Reddy’s Institute of Life Sciences, Hyderabad, May 2017
3. Regulation of mitochondrial dynamics under metabolic stress. Indian Drosophila Research Conference, IISER, Bhopal, December 2017

Jana, Anukul
1. Coordination Chemistry of Germanium(0): Syntheses of Molecular Complexes Containing Formally Neutral Iron Germanide Motifs. Anorganisch-Chemisches Kolloquium, Goettingen, University of Goettingen, Germany, October 2017
2. Reactivity Enhancement of a Diphosphene by Reversible N-Heterocyclic Carbene Coordination. Chemistry and Physics of Materials Unit, JNCASR Bangalore, November 2017
3. Coordination Chemistry of Molecular Mono - and Dicoordinated Germanium(0). Department of Chemical Sciences Annual Talks 2017, TIFR Mumbai, Nov 2017
4. Heterodimer of N-Heterocyclic Carbene (NHC) and Cyclic Alkyl Amino Carbene (CAAC): Influence of Substituents. School of Chemistry, University of Hyderabad, UH-TIFRH Seminar Series, Dec 2017
5. N-Heterocyclic Carbene (NHC) and Cyclic Alkyl Amino Carbene (CAAC) Heterodimers: Influence of N-Substituents. MTIC-XVII, Pune, December 2017
6. Reactivity Enhancement of a Diphosphene by...
Reversible NHC-Coordination: Influence of N-Substituents. Department of Inorganic Chemistry, IACS Kolkata, December 2017

7. Recent Advances in Chemistry of Carbene: Compounds Involving Low-valent Carbon. Department of Chemistry, Prabhat Kumar College, Contai, West Bengal, December, 2017

8. Mono- and Dicoordinate Germanium(0) as Four Electron Donor. Department of Chemistry, IISER Kolkata, January, 2018

9. Recent Advances in Main Group Chemistry: Compounds Involving Low-valent Low-coordinate Elements. Ramakrishna Mission Vidyanandita, Belur Math, Howrah, January, 2018

10. Recent Advances in Main Group Chemistry: Efforts to Mimics with Transition Metal Chemistry. R. K. M. Residential College, Narendrapur, Kolkata, Jan 2018

11. Mono- and Dicoordinate Germanium(0) as a Four Electron Donor. Department of Chemistry, IIT Kanpur, March, 2018

12. Mono- and Dicoordinate Germanium(0) as a Four Electron Donor. Department of Chemistry, IIT Madras, March, 2018

Karmakar, Smarajit
Plasticity, Rheology and Nonlinear response in Driven Amorphous Solids, Grenoble, France, June 2017

Krishnamurthy, M.
1. Building a compact neutral atom accelerator. IISER Pune, 2018
2. Acceleration of neutral atoms in intense laser fields. Special lecture on DPS day, IISER Kolkata, 2018
3. Bringing stars down to a lab. National Science Day, RGUKT, Basra, 2018
4. Extreme Light: a window to extreme matter. Science day lecture, Indian Physics Association, Hyderabad Central University, Hyderabad, 2018
5. Neutral atom generation in intense laser plasma. IISER Tirupati, 2017

Mandal, Kalyaneshwar
1. A Mirror Image Protein Antagonist of VEGF-A Function. Dr. Reddy's Institute of Life Sciences (DRILS), Hyderabad, April 2017
2. Systematic development of novel therapeutics against malaria. Wellcome Trust/DBT India Alliance annual Fellows’ meeting, May 2017
3. Designing Nonnatural Proteins to Inhibit Natural Protein-protein Interactions. Department of Chemical Sciences Annual Talk, TIFR, Mumbai, November 2017

Mazumder, Aprotim
1. Panelist, Presision 2017 (an undergraduate research conference), Kolkata, April 2017
2. Measuring cell-cycle dependent DNA damage responses on a cell-by-cell basis from image analysis. Bioquest 2017, University of Hyderabad, October, 2017
3. Measuring cell-cycle related DNA damage responses on a cell-by-cell basis from microscopic image analysis. ICCB2018, Leonia Resort Hyderabad, January 2018

Mondal, Jagannath
3. Mechanistic pathways of recognition of a solvent-inaccessible cavity of protein by a ligand. American Chemical Society Fall meeting, Washington DC, USA, August 2017
5. Self-organization inside E. Coli. IIT Gandhinagar, February, 2018
6. Atomistic resolution mechanism of ligand recognition in L99A T4 Lysozyme. BITS Hyderabad, February 2018

Mote, Kaustubh, R.
Multiple Sequential Acquisition Strategies to speed up experiments in solid state NMR. Grossbothen, Germany, September 2017

Narayanan, T. N.

Rajalakshmi, G
1. Low field NMR using optical magnetometry. Emerging Trends in NMR One-Day Symposium, TIFR Hyderabad, 25 August 2017
2. Low field NMR using optical magnetometry. TIFR Hyderabad High Field NMR Facility: Inaugural Symposium, TIFR Hyderabad, 13 – 14 February 2018

Ramadas, Jayashree
2. Supporting science in local schools – An outreach initiative of TIFR Hyderabad. College for Integrated Studies, University of Hyderabad, 2 August, 2017

Raman, K. V.
Emerging trends in condensed matter physics. IACS Kolkata, January 2018

Sengupta, Surajit
1. The equilibrium transition underlying irreversible deformation of solids. French-Indian meeting on plasticity and rheology in amorphous solids, in connection with glassy dynamics, Grenoble, France, June 2017
2. The equilibrium transition underlying irreversible deformation of solids. Correlation and disorder in classical and quantum systems, ICTS, Bangalore, May 2017
3. Modelling of plastic response of solids. Fracmeet School, IMSc, Chennai, February 2018

Vig, Monika
1. CRAC Channels: The molecular basis and immunological benefits of being selective. Dr. Reddy’s Institute of Life Sciences, Hyderabad
2. High affinity interactions governing the optimal assembly and selectivity of CRAC channels. Annual Symposium, Department of Chemical Sciences, TIFR, Mumbai

Conferences organized by the Centre

NMR Meets Materials
TIFR Hyderabad, May 5-6, 2017

Emerging Trends in NMR: One-Day International Symposium
TIFR Hyderabad, August 25, 2017

NMR Meets Biology
Grossbothen, Leipzig, Germany, September 3-8, 2017

Teacher workshop Atoms to Amoeba
TCIS, Hyderabad, 12 October, 2017

EMBO Global Exchange Lecture Series
TIFR Hyderabad, 01 Feb, 2018

TIFR Hyderabad High Field NMR Facility: Inaugural International Symposium
TIFR Hyderabad, February 13-14, 2018

TIFR-UoH Life Sciences seminar series (with colleagues from the University of Hyderabad)
TIFR Hyderabad

Non-DAE Research Projects

Agarwal, Vipin (with Yusuke Nishiyama)
Selective recoupling of Protons in fully protonated molecules (Funded by Japan Society for the Promotion of Science); Duration: 1 month

Chandrasekhar, V.
Funded by J. C. Bose Research Fellowship, SERB), Duration: 2017 – 22

Dani, Adish (Co-Investigator)
1. Excitation and excitotoxicity in cochlear afferents: synaptic structure and function (with Mark Rutherford (PI); Funded by NIH, USA (National Institute of Deafness and Communication Disorders)), Duration: Mar 01, 2016 –
Das, Tamal
1. Funding Agency: Max Planck Partner Group award, Max Planck Society Germany, Duration: March, 2017 – February, 2020
2. Mechanobiology of cell competition: Elucidating the role of mechanical forces in cell-cell sensing and collective fitness measurement towards tumor suppression in epithelial tissues (Funded by Wellcome Trust/DBT India Alliance), Duration: January 2018 – December 2022

Garai, Kanchan
Funding agency: DST ECR Grant 2015

Jana, Anukul
1. Rational design for the syntheses of multiple bonded compounds involving heavier Group 14 elements and their reactivity, File No: EMR/2014/001237 (Funded by DST-SERB, India), Duration: 2015 – 2018
2. Syntheses and Reactivities of Compounds Involving Formal Zero Oxidation State of Mono- and Di-Nuclear Group 14 Elements, File No: NS/5747 (Funded by CSIR, India), Duration: 2016-2019
3. Molecular Manifestations of Transition Metal Tetrelides MxEy (M = Cr, Mn, and Fe; E = Si and Ge) for Thin Film Deposition (Funded by AvH Foundation, Germany), Duration: 2017-2019

Krishnamurthy, M.
Developing control systems for Laser based accelerators (a TIFR-RAL collaboration project funded by RAL, UK), Duration: 3 years

Madhu, P. K.
1. Transiently formed non-native conformers of transthyretin: Structure, function and their roles in formation of amyloid fibril (Funded by DBT)
2. Novel nanocatalysts synthesis guided by DNP NMR (Funded by IFCPAR/CEFIPRA)

Mandal, Kalyaneshwar
Systematic development of novel therapeutics against malaria

Mazumder, Aprotim
Developing novel methods for single cell detection of transcripts and proteins in primary cells and tissue to explain variable sensitivities of body cells to DNA-damaging chemotherapeutic agents (Funded by SERB Early Career Research Grant), Duration: 3 years

Mondal, Jagannath
Mechanistic Investigation anti-microbial peptides in action using large-scale computer simulations (with Xiao Zhu; Funded by Extreme Science and Engineering Discovery Environment (XSEDE), USA for Computational allocation (allocation provided in San Diego Supercomputer)), Duration: September 2016 - August 2017

Mote, Kaustubh R.
Continuation of the Project titled ‘Structural and mechanistic characterization of the Mitochondrial Pyruvate Carrier Complex’ (Inspire Faculty Award (DST)), Duration: 2015-2020

Narayanan, T. N.
1. Development of Graphene and MoS2 based van der Waals Solids for Smart Sensors (Funded by DST-Extra Mural Research Grant (Individual Centric) DST-SERB), Duration: 3 years (2017 – 2020)
2. Development of Graphene based Functional Coatings for Possible STP and ETP Technologies (Funded by Private Sponsored Research - M/s Southern Cogen Systems Pvt. Ltd. (SCOGEN), Mysore-571302, Karnataka), Duration: 1 year (2018 – 2019)

Raman, K. V.
1. Funding agency: Ramanujan Fellowship, Duration: 2013 – 2018
2. Funding agency: SERB Early Career research grant

Vig, Monika
CRAC channel components and molecular basis of store-operated calcium entry (1 R01 AI108636-01 (Vig); Funded by NIH/NIAID), Duration: 2018 – 2019
Research and Development in Science, Technology and Mathematics Education

The research projects in science, mathematics and technology education in HBCSE can be broadly grouped under three categories: Learning and Reasoning with Representations, Teaching and Pedagogy, Policy and Curriculum Redesign. Projects in the first two categories work towards improving teaching/learning within the current curriculum, projects in the last category seek to critique and extend the existing curriculum and policies.

Learning and Reasoning with Representations (LRR)

Interactive simulation to learn vectors

The interactive simulation in Javascript, developed for teaching and learning vectors, was tested systematically in the field, using three control classrooms (no simulation; 120 students) and three study classrooms (with simulation; 120 students). Preliminary results from this controlled study were presented at the INTERACT, epiSTEME7 and Future of Learning conferences. The complete analysis of this data is ongoing. [D. Karnam, H. Agrawal, A. Sule, S. Chandrasekharan]

Differences in problem identification and problem solving between adults and children

A range of innovations registered on the website of the National Innovation Foundation were analysed to understand the differences between adults and children in problem identification and problem solving. Students and adults had submitted these innovative ideas, without any design brief by any external agency, and they tackled a range of problems from diverse areas. Contrary to conventional wisdom and literature which suggest that children are more creative than adults, we found a greater diversity in the problems tackled by adults. There were other qualitative differences as well in the kinds of problems identified by adults and children. Interestingly children identified many problems related to human behaviour and attempted to fix these using technology. The study results were reported in Design and Technology Education: An International Journal. [S. Datt, S. Chunawala]

Children as film makers

A study was designed to explore the ability of children to communicate through the medium of visuals. The study emerged from a workshop with a group of eight students (studying in grade 4 and 5) who were taught how to use a smartphone to make animated films. After learning the technique, students were asked to develop a story, and they animated it using snapshots of paper cut-out drawings. Some students communicated their story more effectively through film than others. Their stories had a clear narrative structure, with a beginning, middle and an end. The results align with larger educational research, which show drawings can be used as a means for understanding visual communication in children, especially in the form of visual narratives. [S. Datt, S. Chunawala]

Role of representations when teaching multiplication and division of fractions

A study investigating teaching of multiplication and division of fractions showed that teachers built upon representations given in the textbooks. They formed mathematical explanations that allowed students to make sense of algorithms involved in these operations. However, while the teachers knew the procedures for multiplying and dividing two fractions, how these procedures connected with the representations remained unclear throughout the instruction. Digging
deeper into the teachers’ mathematical explanations around the representations, their meaning-making of students’ responses, as well as their choice of teaching trajectory and examples, showed that making sense of the dynamism within representations, and seeing its parallel in the algorithm, requires a kind of mathematical inquiry that is external to school mathematics. The work was in collaboration with D. L. Ball from University of Michigan. [S. Naik, K. Subramaniam]

The role of artifacts in Kashmiri carpet-weaving

A study was undertaken to examine situated problem solving in Kashmiri carpet-weaving, where different task domains of carpet-weaving practice and solutions were studied. An analysis of different artifacts related to Kashmiri carpet-weaving practice, ranging from symbolic to material, showed that artifacts like talim perform different cognitive functions for different actors. Papers based on these studies were published in two international journals. [G. D. Kaur]

Mechanisms underlying manipulation-based learning

A study of how manipulation of external artifacts changed students’ strategies was done using area problems as the domain. Students who manipulated tangrams before problem-solving had different strategies, and these correlated with eye movement trajectories. A mechanism model of how manipulation of external structures changed internal cognitive structures was developed based on these results. This paper was published in the Cognitive Science Journal, the flagship journal of the Cognitive Science Society. [J. Rahaman, H. Agrawal, N Srivastava (IIT Kanpur), S. Chandrasekharan]

Teaching and Pedagogy

Improving undergraduate biology teaching

The project examines ways to improve biology teaching at the undergraduate level, within the constraints of the current syllabus and resources available to colleges. The sample for our baseline test on basic concepts in biology was extended, and data from more than 300 students was analysed; interesting lacunae in students’ understanding were brought to light. Part of this data, on students’ understanding of sterilization disinfection, was presented at epiSTEME7. [D. Gupta, A. Sawant, S. Patil, N. Bagban, J. Vijapurkar]

Participatory Action Research (PAR) project under School Science Research & Development (SSRD)

This longitudinal project is in its fourth year. The project was initiated with an aim to collaborate with the teachers of a neighbouring Marathi medium school, to enhance learning in environmental and general science. Broadly, the objectives of the project are: understanding the teaching-learning process; preparing instructional materials (worksheets, handbooks/activity manuals); generating simple and inexpensive experiments designed to nurture resourcefulness, and using appropriate teaching aids including audio-visual aids. A month-long summer camp was organized in May 2017 for students entering their grade 5. The students were engaged in activities of stop-motion animation, language, creative writing, design, biomimicry, science and media, and nutrition. In the academic year (June 2017–March 2018), the researchers were involved in preparing lesson plans, work sheets and activities based on the curriculum for grade 5. Additionally, all previous worksheets (3rd and 4th grades) were reviewed and revised. The worksheets and activities for 3rd to 5th grades are being compiled, to prepare a teachers’ handbook on environmental education. A research paper on the conception of the project, and our experiences and learning during the initial two years, was presented at epiSTEME7. The project is carried out in collaboration with school teachers S. Pandilwar and V. Chavan. [J. Ramadas, S. Chunawala, N. Deshmukh (Program Coordinator), S. Bhide, S. Datt, R. Karandikar, V. C. Sonawane, P. Navale, A. Muralidhar, K. Hambir, V. Pawar, T. Adangale, N. Sonawane, R. Shinde, A. Dolas, P. Monteiro, M. Pawar, P. Patil]

Knowledge demands while learning to teach responsibly

Teachers’ knowledge of students’ mathematical thinking informs teaching practice. Existing research reveals that teachers respond to a reform context through resorting to traditional or hybrid pedagogies. A research study was designed to explore and enhance teachers’ knowledge of students’ mathematical thinking, through a systematic investigation of, and reflection on, teachers’ practice in a reform context. We analysed how a teacher begins to make sense of her students’ mathematical thinking as she engages in unpacking mathematics underlying student utterances, and develops deeper knowledge of specific topics. Through a discussion of paired episodes from teaching
of the same (sub) topic over two consecutive years, we identified aspects of teacher noticing and decisions. A study of how a primary teacher with “transmissionist” beliefs radically changed her approach to the teaching of the long division algorithm, showed how in situ interventions with feedback can be powerful in inducing change in teachers’ beliefs and practices. [S. Takker, K. Subramaniam]

**Policy and Curriculum Redesign**

**Terrace farming in schools as a way to promote environment-oriented behavior**

A terrace farm has been set up in a suburban school in Mumbai, to understand how environment oriented actions and behavior could be promoted among urban school students by introducing them to terrace farming. Results from the study were presented at epiSTEME7 and the 7th EcoJustice and Activism Conference. The study shows that the farming practice led to students taking up community-level environmental issues (such as farming in their own apartment complexes), as well as developing closer bonds with their grandparents, who have farming experiences. The school farm is very popular with students, parents and teachers, and there is demand for setting up similar farms in other schools. [D. Dutta, S. Chandrasekharan]

**Teachers’ attitudes towards inclusive education in Indian context**

Teachers’ attitudes are gateways to understand their beliefs, vision, and their likely behavior in inclusive classrooms. In the Indian context, where inclusion is still in a nascent stage, many studies categorise teachers’ attitudes as ‘positive’ or ‘negative’, without unpacking the different type of disabilities these attitudes could be referring to. Indirectly, this could lead to disregarding the role of type (and severity) of disability as influencing factors in shaping specific attitudes. We conducted a survey of middle school teachers in India to micro-analyze their attitudes, using a lens of ‘disability type’ and explored through interviews causal reasons for positivity (or negativity) of such attitudes. The final survey was deployed in 97 middle school teachers, and semi-structured interviews were conducted to gain better understanding of the attitudinal data, by coupling it with the additional dimension of teachers’ perspectives on inclusion in their own classrooms. Results indicate higher positive attitudes towards inclusion of students with ‘orthopedic challenges’. Concerns were raised about inclusion of students with disabilities related to vision, speech and hearing. Some negative attitudes arose from teachers’ concerns about pedagogic challenges in inclusive classrooms. Teachers with prior experience with students with disabilities were more positive towards inclusion. They highlighted the importance of technology in inclusive classrooms, and recommended reforms in pre-service and in-service training to infuse such technology in classrooms. [A. Sharma, D. Chari, S. Chunawala]

**The visual rhetoric of biology**

A project was started to examine the intermixing of knowledge and rhetoric in the visual discourse in biological sciences. A discourse analysis of how biological diagrams in textbooks and online educational resources captured motion and agency was done. The results showed that persuasion in biological diagrams worked in subtle ways, such as the illustrator’s choices of implicit motion through the lines and shapes, as well as the choices of colours, to suggest agency (or lack thereof). Currently science illustrators are being interviewed to probe how their disciplinary and socio-cultural background, philosophical beliefs, and interaction with the editor/publisher, influences the illustrations that are created, and their rhetoric. [C. Navare]

**Designing learning contexts to address graphicity**

The ability to understand, interpret and construct graphics is termed graphicity. Even though considered an important element in science, various studies show that understanding and constructing of graphs does not come easily to learners. A study analysed the graphs in school textbooks, developed and designed a framework for designing learning contexts to improve graphicity, and field tested the learning contexts designed using this framework. The work also reviewed the research done in the area of constructing and comprehending graphs in various domains and various levels. Results show that the graphical practices present in textbooks of different subjects do not build on each other; the presence of graphs is mostly limited to elementary tasks with very few investigative or research-oriented task and design and integration of graphs with the main text need to change for better comprehensibility. [A. Dhakulkar, Nagarjuna G.]
Curriculum and Material Development

Design and Technology Education Group Website and Brochure

Design and Technology Education Group released its new brochure in December 2017 and launched its website (https://dnte.hbcse.tifr.res.in) in January 2018. The website is continually updated. Apart from sharing our research, publications and events on the website, we are also currently developing a resource section. This section will comprise of resource sheets and posters which will be made available freely as ready-to-print formats from the website. A few resource sheets have already been uploaded and these are multilingual, at present in 3 languages (English, Hindi and Marathi) [A. Muralidhar, S. Datt, S. Bhide, R. Shinde, A. Dolas, S. Chunawala]

Vigyan Pratibha

The Vigyan Pratibha project responds to the nation’s concerns about the acute shortage of high quality science and technology specialists in the country by taking a long term view and focusing on growing talent among students with high potential to contribute to science. The programme focuses on students of Class 8–10 in Kendriya Vidyalayas (KVs), Navodaya Vidyalayas (JNVs), and Atomic Energy Central Schools (AECSs). The programme is to be implemented through Science Circles in schools, which will be spaces where students can explore science and mathematics through the Learning Units (LUs) facilitated by their teachers. The LUs are being developed by HBCSE in partnership with resource persons from several scientific institutions in the country.

Pre-pilot phase: Baseline Survey for Vigyan Pratibha

To develop relevant, meaningful and age-appropriate activities for students of KV, JNV and AECS schools, it was decided to conduct a baseline survey in 10 representative schools which included a protocol for interviewing principals, a Likert scale based questionnaire and a protocol for conducting focus group discussion with teachers, a school observation protocol and bi-lingual questionnaire for students. A report of the baseline study was prepared and reviewed internally.

Launch of Vigyan Pratibha

The project was formally launched on July 31, 2017 by Dr. Sekhar Basu, Secretary, DAE, in a joint function at HBCSE, Mumbai and SINP, Kolkata, connected through a video link. Scientists, principals, teachers and students who were part of the pre-pilot phase were present.

Resource Generation Camps

Since its launch in July 2017, HBCSE has organized two resource generation camps (RGCs) for developing LUs. About 50 resource persons from various research institutes, colleges and universities in India have participated in the RGCs. Some of the institutes, colleges and universities that were represented were Indian Institute of Science Education and Research (IISER) Kolkata, Shiv Nadar University, Ruia College, Hyderabad Central University (HCU), Chennai Mathematical Institute, Center for Excellence in Basic Sciences, Tata Institute of Social Sciences Hyderabad, IISER Pune, Ruparel College. The RGC was also attended by a few teachers from AECS, JNV and KV schools.

An interactive web-portal (vp.hbcse.tifr.res.in) has been developed which hosts the LUs and support material for teachers for conducting these LUs in schools. The learning units span topics ranging from fibers, corrosion on metals, microbial growth in curd, osmosis, diffusion, optical reflection, relating shadow on an objecting in sun to time of the day, understanding adolescence and gender, industrial melanism, magnetism, area and perimeter of rectangles, colouring a map with minimum number of colours, a Euclid’s game on observing patterns in numbers, observing birds’ behaviour in surrounding, exploring micro-organisms in your surroundings, studying rice varieties etc. These LUs are simple to conduct with easily available resources, but have potential of scholastic development in the students.

Teachers’ Workshops

The LUs have been conducted with the teachers through two workshops (September 2017 and January 2018) at HBCSE and November 2017 at SINP. Details of these workshops are provided in the section on Teacher and Teacher Educators’ Professional Development.

School Visits

From November 2017 to February 2018, various HBCSE members visited 7 schools and observed 11 LUs being conducted by teachers. In addition, we have

Science Education Material in Hindi

E-learning Portal in Hindi

During the period of this report, the innovative and independent e-learning portal in Hindi (http://ehindi.hbse.tifr.res.in) was upgraded with addition of educational contents. The portal was redesigned and developed on new wordpress platform. The web version of the pedagogic presentations of HBCSE's 5th National Workshop on Development of Educational E-materials in Hindi held in November 2016 have been uploaded. The workshop aims at developing educational contents for Hindi medium science students and teachers up to higher secondary level in the country. The portal has a variety of curricular, co-curricular, and popular science materials that include pedagogic presentations, books, lectures, magazines, articles, reports and reviews in digital form. [K. K. Mishra, D. Mishra, A. Sankhwar, R. Nichat]

Activities of the Hindi Cell and Rajbhasha Samiti

The Hindi Cell was involved in promoting the use of Hindi language in general at the Centre and in particular in the area of development of educational and popular science materials. Hindi Cell arranged a presentation of its science e-learning portal for visiting students and teachers at HBCSE on National Science Day. [K. K. Mishra, D. Mishra, M. Bamne, A. Jadhav]

Science Education Material in Marathi

In collaboration with Maharashtra Rajya Vishwakosh Nirmiti Mandal (a body of State Government of Maharashtra), HBCSE is working to produce Kumar Vishwakosh (KV, an encyclopedia for children in Marathi) on ‘Biology and Environment’ as a reference material for students and teachers at the secondary and higher secondary school level. During the period of this report, we have arranged 8 five-day meetings to finalize the articles and pictures. Kumar Vishwakosh team completed the KV vol. 3 in August 2017 consisting of about 250 articles (with pictures) developed in unicode at HBCSE. The Vishwakosh Mandal is expected to release an internet version very soon. Currently, the editorial committee is working on Kumar Vishwakosh–vol. 4. [H. C. Pradhan, V. D. Lale, A. Aigaonkar, P. Parab]

Knowledge lab

The lab executed several projects in collaboration with the CLIx team from Tata Institute of Social Science and Central Institute of Educational Technology, NCERT, and CUBE. The GStudio platform developed during the past three years was deployed this year on a much wider scale. The platform features can be broadly divided into (a) curation of open educational resources and (b) an activity based collaborative distributed-learning environment (ABCDDE). The former was deployed as the National Repository for Open Educational Resources (https://nroer.gov.in/) and the latter was deployed through the CLIx (Connected Learning Initiative) within the school’s computer labs. The ABCDE content management system was launched for developing and delivering collaborative workspaces and courses in June 2017 at https://abcde.metastudio.org. The platform reached about 500 schools during this year distributed in four states (Rajasthan, Chattisgarh, Telangana, and Mizoram). Apart from the design and development, the lab trained and transferred the technology to the CLIx team through workshops and regular meetings with the technology team. We developed a decentralized and distributed disk which can be copied and distributed to schools. The multi-partner CLIx project was awarded the UNESCO King Hamad Bin Isa Al-Khalifa prize for ICT in Education for the year 2017.

The NROER platform had a major upgrade that included several new features: Collaborative workspaces for each member and partner of the platform; support for H5P content to build interactive assessments; localization support for Indian languages; Course Management System (CMS) and Learning Management System (LMS); a fast and configurable search engine based on elastic search technology; analytics engine for assessment and usage statistics;
Like every year, the lab hosted internships for about 15 students of BITS-Pilani, formally called Practice School, from May 15 – July 15, 2017. The students worked on four different software development projects in the lab contributing to some of the experimental projects:

1. gnowdb development using Clojure and Neo4j based on GNOWSYS specification, (https://github.com/gnowledge/gnowdb/)
2. Search Engine for gstudio platform using Elastic Search, which is eventually integrated as part of the NROER platform,
3. Search Engine for DOER, and
4. Visualization of dependency graphs

External members involved in the above mentioned projects were K. Aitawdekar, R. Katkam, S. Barawadkar, M. Nachankar, R. Swaminathan, and S. Mulla from CLIx Team and S. Dangar, A. Moralwar, M. Tirthakar from the CIET NCERT. [Nagarjuna G., M. Kharatmal, S. Shende, U. Shah, S. Patil, A. Pardeshi]

Collaboratively Understanding Biology Education (CUBE)

Through the CUBE model, we are spreading the idea that through the context of maintaining a model organism, followed by long-term collaborative experimental engagements through social media biology education could be conducted. During the sixth year of CUBE programme, the focus shifted to expanding to several new hubs (locality labs) across the country. We conducted several workshops through the year. The network of active members rose to about 2000 across the country from about 100 different locations. This network is maintained through the instant messaging system (such as Whatsapp, Telegram, and mailing list) and other social media (such as Facebook). With the resources from the center both in terms of time and space remaining the same, the CUBE network could be sustained mainly due to past senior students who mentor the newcomers each year. The research activity of analyzing the quality of engagement and the outcomes is underway through discourse analysis following the methodology of group cognition. This year the online reporting of CUBE activities was initiated through a new online portal called Activity Based Collaborative Distributed Engagement: (https://abcde.metastudio.org/cube), where students post stories as well as “Breaking News” of their work, as blog posts and upload pictures/videos, etc.

During this process, we were able to innovate on designing frugal methods of maintaining model organisms such as Hydra, which otherwise needs sophisticated setup and continuous attention. Nonverbal documentation of some of the activities such as movie making by the students on Seasonomics, tree mapping, on lab protocols such as media preparation, DNA extraction in a frugal lab like a kitchen or a school lab etc., also engaged the attention of students. Several fabrication & DIY activities were developed during this year, for example developing a simple fabricated microscope by inverting the lens of Webcam and using glass slides in order to make the microscopic stage, which is economic and can be used in any schools/colleges. CUBE lab successfully involved about 300 participants in Mango mapping project from 18 different states, which helped in mapping of about 1000 mango trees across India, where participants share an image of a tree with date and place. The outcome of this activity was building an extensive network of participants through personal interaction, getting students as well as citizens sensitized about their environment as well as understanding seasonal variations in flowering & fruiting, the effect of latitude & longitude, photoperiodism, etc. During the next year, we plan to integrate this activity with Season Watch programme initiated at NCBS Bengaluru in collaboration with Nature Conservation Foundation (http://www.seasonwatch.in/).

CUBE lab organized several meets this year. This includes CUBE Young Scientist Meet at CUBE Lab (HBCSE, 21 April, 2017). Here 65 students from 15 different schools across Maharashtra visited CUBE Lab. Model systems such as moina, earthworm, mosquito, fruit fly, Projects on prediction & prevention of mosquito borne diseases like dengue, malaria, etc., Trapping fruit flies to understand activity rhythm in flies and to connect it to sleep studies were introduced. CUBE-Shrushtigyan-Aamchi Shala Meet was organized on April 19, 2017. Here, 25 school students from Shrushtigyan and Aamchi Shala visited CUBE Lab. External resource persons invited included A. Mule (Visiting faculty, Biology section, Centre for Excellence in Basic Sciences) and M. Gaikwad (Lecturer, Department of Biotechnology, Elphinstone college). [M.C. Arunan, Nagarjuna G., M. Kharatmal, J. Advani]
Chemistry Education

Development of inquiry based instructional material for undergraduate organic chemistry

A collaborative project between HBCSE and teachers from colleges of Mumbai and Pune aimed at development of inquiry based instructional material for undergraduate organic chemistry has been going on at HBCSE since August 2016. This work was continued this year and covered following topics – hybridisation, resonance, polarity and dipole moment, inductive effect, aromaticity, acids and bases, electrophiles and nucleophiles and reactive intermediates. Some of these developed activities are tested at the NIUS chemistry camps for feedback and are being modified further. [S. Ladage, G. Carneiro (formerly, Sophia college, Mumbai), G. Shaikh (formerly, St. Xavier college, Mumbai), G. Shridhar (V. K. Krishna Menon college, Mumbai), L. Ravishankar (KET’s Vaze college, Mumbai), T. Parulekar (SIWS college, Mumbai) and S. Kale (MES Abasaheb Garware college, Pune)]

A Book on Chemical Thermodynamics

A book titled “Basics of Chemical Thermodynamics” has been written as part of development of instructional material for undergraduate chemistry education. This work is part of NIUS chemistry programme. The book adopts pedagogic method of teacher-student dialogue to highlight the conceptual pitfalls in this area of physical chemistry. It has a large number of illustrative examples and covers essentially all of thermodynamics at the undergraduate level. Few copies of the book have been printed for pre-publication review process and the book will be uploaded on HBCSE NIUS website in the near future. [A. Kumar, S. Ladage]

Olympiads and Related Activities

The Olympiad programmes in Astronomy, Biology, Chemistry, Junior Science, Mathematics and Physics in India continued to flourish in 2017 – 2018 with the dedicated hard work of the HBCSE Olympiad cell members, the teacher associations and many resource persons from across the nation. The programme provides a benchmark for high achievement in science and mathematics at the secondary, higher secondary and, by extension, even at the undergraduate level in the country. The Olympiad programme has provided a platform for school, college and university teachers as well as researchers in esteemed institutions to meet and interact with each other. Nearly 300 teachers and researchers attended resource generation and exposure camps held at HBCSE, and were involved in designing conceptual and challenging problems and developing novel experiments. Most of these resources have been made available through the Olympiad problem books published by HBCSE and some have also appeared as publications in peer-reviewed technical journals.

Out of the 30 students who represented India in the International Olympiads in 2017, 10 won gold medals, 12 silver, 4 bronze and 4 honourable mentions. Over 200 of the best students from across the nation were given experimental and theoretical training at HBCSE.

Indian National Olympiad

The Olympiad selection procedure in all the subjects (Astronomy, Biology, Chemistry, Junior Science, Mathematics and Physics) followed the standardized routine. The first level tests in science subjects (the National Standard Examinations, NSEs) were held on November 19 and 26, 2017 at about 1400 centres spread all over the country. These were conducted by the Indian Association of Physics Teachers (IAPT), with the assistance of Association of Chemistry Teachers (ACT) and Association of Teachers in Biological Sciences (ATBS). The NSEs had mainly objective type questions. The participation in the NSEs for the year 2017 – 18 was as follows: 19893 in Astronomy, 34206 in Biology, 56192 in Chemistry, 48309 in Junior Science, and 58688 in Physics. This amounts to an increase of about 70% in Biology, 50% in Junior Science, 35% in Physics and Chemistry, and 20% in Astronomy, over last year. In mathematics, the first stage had two sub-stages: the Pre-Regional Mathematical Olympiad (PRMO) and the Regional Mathematical Olympiad (RMO). The PRMO was organized nationally by IAPT and involved 100197 students. The RMO was organized regionally and involved 14943 students.

The second level examination for the science subjects, the Indian National (Astronomy / Biology / Chemistry / Junior Science / Physics) Olympiad Examinations (INAO, INBO, INChO, INJSO and INPhO, respectively) were conducted by HBCSE at 18 centres nationwide on January 27 – 28, 2018. These tests had subjective problems, and were of high difficulty level,
somewhat comparable to the international Olympiads. The number of students selected for this examination (on the basis of performance in the first level, NSEs) were as follows: 527 in Astronomy, 309 in Biology, 596 in Chemistry, 370 in Junior Science and 396 in Physics. Similarly, the second level examination in Mathematics, the Indian National Mathematical Olympiad (INMO) held on January 21, 2018 was taken by 940 students. The number of students selected for the next level, the Orientation – Cum – Selection Camps (OCSC) in science subjects, and Indian Mathematical Olympiad Training Camp (IMOTC) were as follows: 51 in Astronomy, 36 in Biology, 35 in Chemistry, 41 in Junior Science, 36 in Physics, and 50 in Mathematics.

**Orientation – Cum – Selection Camps (OCSCs)**

Students from the previous batch (2016 – 2017) attended the OCSCs in different subjects at HBCSE during April – June 2017. The camps consisted of lectures, tutorials and experimental/observational sessions. The selection of Indian teams for the international Olympiads was based on the performance of the students in several theoretical and experimental/observational tests in these camps. The selected teams for international Olympiads went through two weeks of Pre-Departure Camp (PDC) at HBCSE.

**Astronomy**

The Astronomy Olympiad Cell conducted Orientation Camp during April 22 – May 8, 2017 and Pre-departure camp (PDC) for the Indian team in November 2017. 51 students were selected for the camp out of which 25 students attended the OCSC. Astronomy OCSC programme covers a wide range of topics in astrophysics from positional astronomy, stellar and solar physics to large scale structure of the universe and cosmology. The students were evaluated on basis of 3 theoretical, 2 practical and 2 observation tests conducted during the camp and top 5 students were selected for merit awards and the Indian team for the international Olympiad. D. Bhattacharya, (Senior Professor, IUCAA, Pune) delivered a scientific lecture on “ASTROSAT: India’s space observatory”, at the Astronomy OCSC Valedictory Function which was held at HBCSE on May 8, 2017.

The five-member team at the 11th International Olympiad on Astronomy and Astrophysics held at Phuket, Thailand from November 12 – 21, 2017 won one Gold and three Silver medals and one Honorable Mention. A. Mazumdar (HBCSE) and N. Banerjee (IISER Kolkata) were the team leaders and M. N. Vahia (TIFR, Mumbai) and A. M. Srivastava (IOP Bhubaneswar) were the scientific observers. [A. Sule, A. Mazumdar, P. Ranade, K. Raodeo, P. Parte, M. N. Vahia and external resource persons]

**Biology**

The Biology Olympiad Cell conducted OCSC during June 1–10, 2017 and the PDC for the Indian Team in July 2017. 36 students were selected for the camp out of which 30 students attended the OCSC. Problem solving sessions in Cell Biology, Plant Sciences, Animal Sciences, Genetics & Evolution, Ecology and Ethology were conducted. Lab orientations and tests in the four lab areas namely Plant Anatomy & Physiology, Animal Anatomy, Developmental Physiology, Biochemistry, Molecular & Cell Biology were conducted during this camp. The following experiments were standardized and given as tasks in the various lab selection tests and during the lab orientation sessions:

1. Comparative study of algae, separation of pigments, study of absorption spectrum of plant pigments, study of plant tissues.
3. Study of enzyme activity, determination of unknown concentration of Congo red and study of enzyme expression in *Saccharomyces cerevisiae*.
4. Extraction of nucleic acids and agarose gel electrophoresis, amplification and analysis of nucleic acid samples and blood group typing.

The four-member team to represent India at the international Olympiad was selected on the basis of two theoretical tests and four experimental tests during the camp. S. Sane (NCBS Bangalore) delivered a scientific lecture on “How do insects fly”, at the Biology OCSC Valedictory Function which was held at HBCSE on June 10, 2017.

The 4 member Indian team at the 28th International Biology Olympiad held at Coventry, United Kingdom from July 23 to 30, 2017 won three silver medals and one bronze medal. A. Ronad (HBCSE, TIFR), P. G.
Kale (R. Jhunjhunwala College, Mumbai) were the team leaders and K. Kondabagil (IIT Bombay), R. V. Devkar (M. S. University, Baroda) were the scientific observers. [R. Vartak, A. Ronad, V. Ghanekar, P. Jadhav, S. Ranmale, H. Chandwani, N. Khan, S. Shelar and external resource persons]

Chemistry

The Chemistry Olympiad cell conducted OCSC during May 23 – June 3, 2017 and the PDC for the Indian Team in July 2017. 35 students were selected for the camp out of which 31 students attended the camp. The lecture sessions at OCSC 2017 were related to chemical thermodynamics, spectroscopy, chemical kinetics, phase equilibria, stereochemical effects in reactions, transition metal chemistry, main group chemistry, laboratory safety, and common laboratory techniques. The theoretical examinations at the camp were related to quantum mechanics, chemistry of erythromycin, thermodynamics, pericyclic reactions, chemical kinetics, silicon compounds, chemistry of chromium and reagents in organic synthesis. Six experiments were developed and standardized for experimental examinations at OCSC 2017 covering the following areas:

3. Determination of the rate constant for the redox reaction between ethanol and chromium (VI).
4. Identification of inorganic compounds by qualitative analysis.
5. Determination of the purity of given sodium salicylate in the solution.

The four-member team was selected at the end of the camp to represent India at the International Olympiad. V. Polshettiwar (TIFR, Mumbai) delivered a scientific lecture on “Can nanotechnology help combat climate change”, at the Chemistry OCSC Valedictory Function which was held at HBCSE on June 3, 2017.

On the basis of camp performance, a team of 6 students was selected for the international event. The Indian team at the 49th International Chemistry Olympiad held at Arnhem-Nijmegen, Netherlands from December 3 to 10, 2017 won four Gold medals and two Silver medals. P. Das Gupta (Retd., Siddharth College of Arts, Science and Commerce, Mumbai), S. Haralkar (Retd, Siddharth College of Arts, Science and Commerce, Mumbai) and R. Khunyakari (Tata Institute of Social Sciences, Hyderabad) were the team leaders. [P. K. Joshi, P. Nawale, S. Pathare, S. Narvekar, V. Ghanekar, S. Mukherjee, B. Chemate, P. Masale, P. Shinde, J. Lad and external resource persons]

Junior Science

The Junior Science cell conducted OCSC during May 9 – 26, 2017 and the PDC for the Indian team was held in November, 2017. 36 students were selected for the camp out of which 32 students attended the OCSC. The camp consisted of around 30 lectures and 22 experimental sessions in advanced topics in Biology, Chemistry and Physics at the Class X level. Problems of high standard were set for theoretical and practical exams. A. A. Natu (IISER, Pune) delivered a scientific lecture on “What we learn from nature”, at the Junior Science OCSC Valedictory Function which was held at HBCSE on May 26, 2017.

On the basis of camp performance, a team of 6 students was selected for the international event. The Indian team at the 14th International Junior Science Olympiad held at Arnhem-Nijmegen, Netherlands from December 3 to 10, 2017 won four Gold medals and two Silver medals. P. Das Gupta (Retd., Siddharth College of Arts, Science and Commerce, Mumbai) and R. Khunyakari (Tata Institute of Social Sciences, Hyderabad) were the team leaders. [P. K. Joshi, P. Nawale, S. Pathare, S. Narvekar, V. Ghanekar, S. Mukherjee, B. Chemate, P. Masale, P. Shinde, J. Lad and external resource persons]

Physics

The Physics cell conducted OCSC during May 27 to June 9, 2017 and the PDC for the Indian Team was held in July, 2017. 37 students were selected for the camp out of which 35 students attended the OCSC. Lectures were delivered on advanced topics such as Fermat's principle, the second law of thermodynamics and modern physics. Theoretical problems in the test were of high standard and included topics such as the catenary shape of a hanging wire, use of the square wheel in transport and magnetic black box. The Indian Physics Association award for a challenging theoretical problem in the OCSC was based on the physics of the indigo molecule, in reference to the centenary of
Mahatma Gandhi’s pioneering Satyagraha movement against forced indigo plantation in Champaran (Bihar). Apart from modification and redesign of some previously developed experiments, two new experiments were designed and developed. These experiments were:

1. Curie Weiss Law in ferroelectrics: Ferroelectrics lose their intrinsic polarization at temperatures above a transition temperature and become paraelectric. Above the transition temperature, the electrical susceptibility ($\chi$) of the substance follows the Curie-Weiss law. A simple method of determining electrical susceptibility is to measure the capacitance of a parallel plate capacitor containing the ferroelectric substance as a dielectric. In ceramic capacitors given to the students, barium titanate ($\text{BaTiO}_3$) is used as the dielectric. With variation in temperature, change in capacitance of the capacitor was studied and using this data the Curie-Weiss law was verified.

2. Birefringence of a cello-tape: There are certain materials like cello tape, which exhibit two different values of refractive index along two, preferred, orthogonal axes. As light travels along these axes they get plane polarized in perpendicular directions. Hence, components of light with different polarization states, move with different speeds as they pass through these axes. Such materials are said to be birefringent. In this experiment, the change in intensity of light as they are transmitted through these materials is studied.

The five-member team was selected at the end of the camp to represent India at the International Olympiad. P. Raychoudhuri (TIFR, Mumbai) delivered a scientific lecture on “Walking through walls: The amazing world of electron”, at the Physics OCSC Valedictory Function which was held at HBCSE on June 9, 2017. The Indian team at the 48th International Physics Olympiad held at Yogyakarta, Indonesia from July 15 to 24, 2017 won four gold medals and one silver medal. S. Pathare (HBCSE) and J. Amalnathan (BARC, Mumbai) were team leaders and S. Bodhane (St. Xavier’s College, Mumbai) and A. C. Biyani (Retd. Govt. Nagarjuna Science College, Raipur, Chhattisgarh) were the scientific observers. [A. Mazumdar, S. Pathare, P. Pathak, S. Shahapurkar, P. K. Joshi, P. Chaudhary, V. Nadkar, A. Jadhav, S. Shirodkar and external resource persons]

Mathematics

The Mathematics Cell conducted IMOTC during April 22 to May 20, 2017 and PDC for the Indian team during July 6 to July 14, 2017. A total of 46 students attended IMOTC. J. K. Verma (Department of Mathematics, Indian Institute of Technology Bombay) and M. Krishnapu (Department of Mathematics, Indian Institute of Science, Bangalore) delivered lectures on “An invitation to Ehrhart theory of lattice points in polytopes” and “In praise of good definitions” respectively, at the Mathematics OCSC Valedictory Function which was held at HBCSE, on May 20, 2017.

A six-member team was selected at the end of the camp to represent India at the 58th International Mathematical Olympiad held at Rio de Janeiro, Brazil during July 12 – 23, 2017. The team won three Bronze medals and three Honourable Mentions. C. R. Praneschar, formerly of HBCSE, Mumbai and V. Vaish (ISI, Bangalore) were the team leaders. M. A. Prasad (Retired Scientist, BARC, Mumbai) and S. Sinha (Student, IISc, Bangalore) were the observers. [P. De and external resource persons]

A two member team was selected to represent India at the Sixth European Girls’ Mathematical Olympiad (EGMO) held at Zurich, Switzerland from April 6–12, 2017. The team won 1 Bronze medal and 1 Honourable Mention. The team was accompanied by B. J. Venkatachala, formerly of HBCSE, B. Sury (National Coordinator, Mathematical Olympiad) and P. Varade (Bronze Medalist in EGMO 2015 and IMO 2015, and currently a student of I.I.Sc. Bengaluru). The EGMO felicitation function was held at HBCSE on April 13, 2017. [P. De and external resource persons]

Resource Generation Camps (RGCs)

Several Resource Generation Camps in which teachers and scientists from across the nation gathered for development of curriculum and Olympiad material were held in all the subjects. The RGCs in Astronomy were held between April 1 – 2, 2017; November 4 – 5, 2017; January 4, 2018. RGCs in Biology were held between November 9–10, 2017; November 22–23, 2017; January 2, 2018 (INBO Board Meeting). RGCs in Chemistry were held during December 3, 2017; January 31 – February 12, 2018. Several RGCs in Junior Science were held during April 8 – 9, 2017; July 22 – 23, 2017; September 23 – 24, 2017; November 4 – 5, 2017; February 3 – 4, 2018; March 17 – 18, 2018. Physics
RGCs were held during October 8 – 10, 2017; December 19 – 21, 2017; February 5 – 9, 2018. The mathematics olympiad cell organized 3 RGCs in May, August (in IISc, Bengaluru) and December 2017 (in HBCSE).

**Exposure Camps (ECs)**

Several short 3–5 day exposure camps were held in different subjects where a large number of school and college teachers were invited. Olympiad problems and experiments were discussed in these camps. Towards the end of the camp the teachers were invited to suggest challenging tasks for the students and critique existing textbooks. Several teachers from Kendriya Vidyalayas and Jawahar Navodaya Vidyalayas were specifically invited to the Exposure Camps of different subjects for the year 2017–18.

The exposure camps for Astronomy was held during October 31 – November 3, 2017; for Biology during November 15 – 17, 2017; for Chemistry during November 23 – 26, 2017; for Junior Science were held during April 22 – 24, 2017 (Bhatinda); June 27 – 29 (Ulhasnagar); October 25 – 27, 2017 (Delhi); February 18, 2018 (Bhilai); March 17 – 18, 2018 and for Physics during November 28 – December 1, 2017. A teacher training programme of Junior Science were held during December 18–20, 2017 (Sawantwadi) and December 21–23, 2017 (Kankavali).

**Infosys Award Function**

The Infosys Award Function for science and mathematics Olympiad medallists of 2017, held on December 22, 2017, was attended by Olympiad medallists, team leaders and observers and parents. The awards, made possible from the generous grant received from the Infosys Foundation, were distributed by the Chief Guest, Arvind Kumar, Former Centre Director of HBCSE. The award function was preceded by 2 scientific lectures delivered by Rupamamanji Ghosh (Vice-Chancellor, Shiv Nadar University, UP) on “Manipulating atoms by light”, and by Jaikumar Radhakrishnan (TIFR) on “It is Entropy that counts”. Videos of the lectures are available on HBCSE’s Youtube Channel.

**National Initiative on Undergraduate Science (NIUS)**

The National Initiative on Undergraduate Science (NIUS) programme of HBCSE has its thrust on development of general scientific competencies among motivated undergraduate students by engaging them in proto-research projects/research like activities. Sustained interactions with mentors and freedom to plan and execute the work, present ample opportunities to NIUS students for deeper engagement with different theoretical and experimental areas of science. Some of the project work carried out by NIUS students were of sufficiently high standards and were published in international journals.

Along with programme for students, active efforts have been made to enhance the interactions with teachers through organization and participation in teacher workshops. HBCSE is keen on initiating the research and developmental activities that are informed by science education research at undergraduate level as part of NIUS programme in near future. For the same, at epiSTEME–7, seventh in a series of biennial conferences initiated by HBCSE, discipline based education research (DBER) with emphasis on undergraduate science education was the new focal theme. Four review talks at the conference covered areas related to DBER at undergraduate level. Thus, NIUS programme is gearing up to impact the teaching-learning scenario at the undergraduate level within the country.

Till date, about 1646 undergraduate students have been exposed to the NIUS programme of HBCSE (as part of exposure-cum-enrichment camps). This year about one hundred and sixty six undergraduate students were invited to attend the NIUS exposure-cum-enrichment camps. During these camps, students interacted with researchers, scientists, and passionate teachers and were actively involved with workshops and laboratory activities. For students coming from regular bachelor courses and non-metropolitan areas, such an exposure is important as it presents vibrant experiences about domain of science.

**NIUS Biology**

The NIUS camp for Biology (XIV.1) was conducted at HBCSE from October 30 to November 3, 2017 and 41 students from regular B.Sc. or integrated M.Sc. courses were selected for the camp. 37 students attended the camp. The external resource persons for the camp were
J. D’souza (UM-DAE CBS, Mumbai), H. Ramchandran (Sophia College, Mumbai), K. Vacchrajani (M. S. University, Baroda), and S. Patankar (IIT Mumbai).

The theoretical sessions at the camp were related to basic concepts in biology, proteins and their structures and interactions, model systems to understand biological complexities. The laboratory sessions covered experiments related to biochemistry, molecular biology and experiments in animal behavior. From this batch, 5 students have been selected to pursue NIUS projects in different areas of biology. In addition, 14 students from earlier batches of NIUS Biology visited HBCSE to continue their projects of whom one student completed the project and was issued a certificate. [R. Vartak, A. Ronad, V. Ghanekar.]

NIUS Chemistry

The NIUS camp for chemistry (XIV.1) was held at HBCSE from December 23–29, 2017 and 51 students from regular B.Sc. / B.S. or integrated M.Sc. courses were selected for the camp. 47 students attended the camp. The external speakers for the camp were D. Dutta (BARC, Mumbai), G. Shaikh (Xavier’s College, Mumbai), G. Shridhar (V. K. Menon College Mumbai), K.R.S. Chandrakumar (BARC, Mumbai), N. Mahadevan (IIT, Mumbai), R.V. Jayaram (ICT, Mumbai), S.S. Bhagwat (ICT, Mumbai) and S.V. Joshi (ICT, Mumbai).

The theoretical sessions at the camp were related to chemical engineering thermodynamics, fundamentals and applications of interfacial science and engineering, stereochemistry of organic compounds, introductory quantum chemistry, role of catalysis – green processes and clean environment, pericyclic reactions, challenges in process R&D and manufacturing of Generic APIs (active pharmaceutical ingredients), interesting molecules of nature, nanotechnology at the interface of physics, chemistry and biology, introduction to computational chemistry, interactions of science and society and chemical wealth in the unwanted. The workshops at the camp were: a) using Inquiry based Learning instructional material to understand concepts in organic and physical chemistry, b) reading of scientific papers from peer-reviewed journals, and c) abstract writing.

The laboratory sessions at the camp covered the following experiments i) analysis of vitamin C in nutritional supplements, ii) synthesis of organic dyes and using them to dye cloth samples, iii) study of breakdown of starch by an enzyme–based digestive syrup and iv) synthesis of inorganic complexes and studying their ligand displacement reactions. These sessions were primarily group activities and involved a) discussion and develop an experimental plan, b) assessment of safety and risk, c) understanding stoichiometry and quantitative aspects of experiments, d) reflections on data and problems faced during conduct of experiments and e) listing possible sources of errors that affected the data. The details of work done were presented as posters by the individual groups.

Towards the end of this camp, 24 students were selected for the project work. In addition, 33 students from earlier batches of NIUS Chemistry visited HBCSE for their project work. In all, 15 students completed their projects either at HBCSE chemistry laboratory (4 projects) and/or at other laboratories and were issued certificates. [A. Gupta, S. Ladage, S. Chunawala, I. D. Sen, S. Narvekar, S. Varadarajan]

NIUS Physics and Astrophysics

The NIUS camp for physics (XIV.1) was conducted at HBCSE from June 13 – 28, 2017 and 74 first year undergraduate students were invited to attend the camp. These students were from three streams i) regular B.Sc; ii) integrated M.Sc. and iii) B.Tech. / B. E. 70 students attended the camp. The external speakers for the camp were A. Dighe (TIFR, Mumbai), A. Joshi (Adelphi University, USA), A. Kumar (Formerly, HBCSE), A. Srivastav (IOP, Bhubaneshwar), D. Banerjee (IIT, Bengaluru), D. Ojha (TIFR, Mumbai), K.R.S. Chandrakumar (BARC, Mumbai), P. Pal (SINP, Kolkata), P. Panigrahi (IISER, Kolkata), S. Das (IIT Kharagpur), S. Jain (BARC, Mumbai), V. Singh (Formerly, HBCSE), and Y. Wadadekar (NCRA, Pune).

The areas covered at the camp were neutrino physics, introduction to quantum mechanics, many body theory in quantum mechanics, quantum computations, quantum mechanics of non-integrable systems, galaxies, stellar structure, stellar structure and stellar oscillations, thermodynamics and statistical mechanics, superconductivity, experimental problem solving, applications of advanced optics, quantum foundation and quantum information and introduction to sun and its long term variation. After the project discussions and evaluation sessions at the camp, 32 students were selected for projects to be carried out at different
institutions. Around 33 students continued their projects in physics and astronomy in summer and winter 2017. Some of them are in the process of completing their projects and prepare their final project reports. 7 students have completed their projects and certificates have been issued to them. [A. Mazumdar, P. Pathak, R. B. Khaparde, S. M. Roy, K. Raodeo and external resource persons]

NIUS Workshops

Active Learning in Optics and Photonics (ALOP) and Experimental Problem Solving (EPS) in Physics

A 3-day workshop for 37 physics teachers from high school, junior college, UG and Physics Education Researchers on Active Learning in Optics and Photonics (ALOP) and Experimental Problem Solving (EPS) in Physics was held at HBCSE, Mumbai during January, 10 – 12, 2018. This workshop had sessions on UNESCO supported Active Learning in Optics and Photonics (ALOP). The ALOP modules consisted of several experiments, demonstrations and activities, which teachers can use in their schools/colleges. Along with ALOP, participants were also introduced to the idea of Procedural Understanding (PU), EPS in Physics and using it as an assessment tool. The workshop was conducted in collaboration with D. Sokoloff from University of Oregon, USA. [R. Khaparde]

Workshops on Organic Electronics

One-day hands-on training workshop on “Organic Electronics” was conducted at HBCSE on December 6, 2017. A. Banerji, Institute of Chemistry Education, University of Cologne, Germany and his team consisting of 12 student members were involved as resource persons for the workshop that had participation of 30 teachers and students across India and HBCSE. This workshop was related to synthesis of organic light emitting diodes (OLEDs) and organic photovoltaic cells (OPVs) and was aimed at integration of current topics of industrial and scientific research such as semi-conducting polymers into school and university curricula by using low cost experiments.

Refresher course on Foundations of Physical Chemistry and its Applications in collaboration with Indian Women Scientists’ Association (IWSA)

A one-day programme was conducted by members of chemistry cell at HBCSE for a refresher course, organised by Indian Women Scientist Association (IWSA). The course titled, Foundations of Physical Chemistry and its Applications, had participation of 25 chemistry teachers teaching at undergraduate/postgraduate level, from colleges / university departments across India on December 18, 2017. The sessions conducted were titled as i) Context based chemistry problems: A route to deeper learning, ii) What is this field of Chemistry Education Research? and iii) Bothering about learning in chemistry laboratory?: A closer look at experiments. [A. Gupta, S. Ladage, S. Narvekar, and I. D. Sen]

Workshop on Advanced Molecular Biology Techniques

A 2-day hands on workshop on Advanced Molecular Biology Techniques was held at HBCSE for 3rd Year BSc. students (19 students) on March 6 – 7, 2017. [R. Vartak, A. Ronad, V. Ghanekar and project personnel, Biology Olympiad Cell]

NIUS Astronomy Winter School

Like every year, past astronomy Olympiad students were invited to participate in a 2 week winter school at an astronomical institution from December 4 – 15, 2017. This year's school held at Indian Institute of Space sciences and Technology (IIST), Thiruvananthapuram was attended by 20 students. The students participated in various projects under guidance of Sarita Vig and Anandmayee Tej. [A. Sule, P. Ranadive]

Teacher and Teacher Educator Professional Development

The Homi Bhabha Centre for Science Education works actively with in-service teachers and designs activities for teacher professional development (TPD) from primary to tertiary education. HBCSE also works with teacher educators involved in the conduct of TPD courses for inservice teaching community. Workshops are also designed and conducted to address pre-service (B.Ed and D.Ed) teachers, and requests for all workshops are received at http://teacher-ed.hbcse.tifr.res.in/

Several faculty, scientific and project staff at HBCSE are involved in Teacher Professional Development (TPD) at various levels. During this academic year, over 50 workshops were conducted at HBCSE and elsewhere for over 700 participants that included science and mathematics teachers and teacher educators and resource persons from identified groups
of schools and teacher education institutes. HBCSE collaborated with several organizations like Kendriya Vidyalaya Sangathan, Shivaji Vidnyan Parishad, District Institute for Education and Training (DIET) Haryana, Muktangan, Azim Premji University, Ramanujam Mathematical Society, Navnirmiti Learning Foundation, Edu-Genie, Bombay Association for Science Education (BASE), Nashik Education Society and Indian Women Scientists’ Association among others.

**Teacher Professional Development under the School Science Research and Development Programme**

The School Science Research and Development (SSRD) programme of HBCSE aims to integrate research, material development and outreach for students, teachers and teacher educators. This collaborative programme entails working closely with schools and teachers to study and improve the quality of science and environmental studies in a participatory mode, for elementary and middle school levels, with the aim of developing resource materials for the same and is actively involved in TPD.

The SSRD group addressed teachers through topics based on design and technology, bio-inspired design, nature of science (NOS), learning science with toys, inquiry and cooperative learning (pedagogical strategies), and science practice (process) skills. The sessions showcased how learning in schools can be made interesting and relevant to learners through the use of design and technology tasks. Activities involved designing for specific needs, making of designed artefacts using available resources and evaluation of existing technologies regarding desired (e.g., sustainability) contexts. Use of such tasks supported an integrated approach to learning and promoted the application of knowledge (e.g., understanding design by examining unfamiliar artefacts, evaluating artefacts for design appropriateness, acquiring, abstracting and applying design inspiration from structures/forms, processes, and systems in the natural world, etc.).

Sessions on NOS included hands-on activities to emphasize fundamental ideas about how scientific knowledge is created and understood. Sessions on pedagogical strategies highlighted and demonstrated the use of the inquiry and cooperative learning approaches in science classrooms. Some of the significant teacher programmes that took place this year are as follows.

The SSRD group and few others organised a 3-day residential workshop for SCERT, at HBCSE from February 8 – 10, 2018. The participants of this workshop were selected by the SCERT Haryana, and referred as District Science Specialists. These specialists were preparing to be the master trainers, and therefore the workshop focused on higher order skills and knowledge. The participants were exposed to tasks around nature of science, and activity based learning. The sessions included the historical and conceptual perspective of various topics in middle and secondary schooling. Few examples are: electricity and magnetism, electronic microscopes and their construction, materials, and fibers and learning from research readings. [S. Narvekar and V. C. Sonawane (Coordinators), K. Subramaniam, S. Chunawala, A. Gupta, S. Narvekar, K. T. Hambir]

Sponsored by Rajiv Gandhi Science and Technology Commission, a two-day workshop was conducted for creating mentor teachers. These mentor teachers were prepared to work in the four Science and Innovation Activity Centres. These mentor teachers developed experiments and activities to be carried out in the respective centres with the help from resource persons at HBCSE. [V. C. Sonawane, K. T. Hambir]

Several one-day workshops were organized by the members of SSRD group. Some notable ones are: Primary and middle school teachers from Trombay Schools, Night school teachers of Masoom Sanstha, Pre-service teachers from various B.Ed. Colleges in Mumbai. [V. C. Sonawane, K. T. Hambir]

Shri Shivaji Education Society, Amravati organised 5th Shivaji Vidnyan Parishad on ‘Science teaching, learning and evaluation: experiences and challenges.’ Members of SSRD group conducted a two-day workshop for 115 teachers on teaching Science effectively and made and used experiments in the classroom. [N. D. Deshmukh, K. T. Hambir]

**Integrating Concepts in Undergraduate Biology Laboratory**

A two day workshop was conducted for Mumbai University teachers involved in teaching undergraduate courses in Biotechnology and Microbiology disciplines. The workshop was held on September 6 – 7, 2017 and was attended by 42 teachers from around 15 colleges affiliated to University of Mumbai. It was aimed at designing simple course embedded research problems
which could act as scaffolds for integrating various experiments which are currently carried out as individual activities. The broad idea was that by adopting workable changes in the curriculum, research experiences can be designed for students which can be implemented even in a large enrollment class. A total of 25 problems were designed by the teachers during the workshop and the developed resources were shared with all the teachers who attended the workshop.

[J. Vijapurkar, D. Gupta, A. Sawant, S. Patil, N. Baghban]

**Teacher Professional Development in Mathematics Education**

The mathematics education group is involved in research around teachers’ professional development and knowledge for teaching. In TPD workshops, an attempt is made to bridge insights from research with the actual practice of teacher education through a focus on pedagogical content knowledge. Use is made of video materials, students' work and curriculum analysis (available at mathedu@hbcse.tifr.res.in) to develop teachers' understanding of mathematics needed for effective teaching.

This year, in continuation with our collaboration with Kendriya Vidyalaya Sangathan, HBCSE members participated in a workshop for KV teachers from across the country. The workshop conducted in January 2018, focused on Pedagogical Content Knowledge in middle grades that sensitized teachers to students’ ways of thinking about mathematics. The group conducted a 3-day residential workshop (February 2018) for the district mathematics specialists, nominated by SCERT Haryana. This workshop focused on preparing the subject specialists as resource persons. The theme of the workshop was “Teaching teachers using artefacts of teaching.” During these 3 days, the specialists worked on various artefacts – teaching videos and scenarios, students’ mathematical work, textbooks, research readings, and lesson study. [K. Subramaniam, S. Naik, A. Kanhere, H. Raval, R. Kumar, S. Narvekar]

Several workshops were organized around mathematics laboratory and problem-solving where teachers engaged with designing, making and using of mathematics activities, games, puzzles, and problems. Tasks around area and measurement, algebraic thinking, proportional reasoning, geometric relationship, and number systems were the core topics of these sessions. We worked with pre-service teachers and primary and middle school teachers from Trombay schools, MA education (TISS) students and YCMOU postgraduate students. As part of the Vigyan Pratibha, in two resource generation camps, we interacted with Kendriya Vidyalaya, Jawahar Navodaya Vidyalaya, and Atomic Energy Central School Teachers. [K. Subramaniam, A. Kanhere, S. Naik, H. Raval]

Ruchi Kumar and Shweta Naik completed their doctoral work in the area of teacher education. R. Kumar studied a TPD workshop conducted by the mathematics education group for Kendriya Vidyalaya teachers and its uptake by following up with the teachers for an entire year after the workshop. S. Naik's work involved observing Mumbai municipal school teachers and analyzing knowledge demands for effective instruction of mathematics. [R. Kumar, S. Naik, K. Subramaniam]

**TPD workshops under Olympiad and NIUS initiatives**

As part of Olympiad programmes, TPD workshops are conducted for teachers teaching sciences primarily at higher secondary and undergraduate levels. These workshops, titled as Resource Generation Camps (RGCs) and Exposure Camps are conducted annually in Physics, Chemistry and Biology. The camps are generally of 2 to 4 days duration and sessions range from designing context based problems in theoretical areas, to laboratory experiments and involve critical discussions regarding concepts in textbooks. The Olympiad section presents the details about these camps. TPD workshops are also conducted as part of NIUS and are primarily for teachers teaching at undergraduate level. Along with content enrichment, such workshops cover sessions related to a) conceptual pitfalls in core topics of the discipline, b) experimental problem designing, c) research informed teaching/learning practices and d) development of instructional material. The details of such camps conducted in Physics and Chemistry are presented in the NIUS section.

**TPD workshops under CUBE initiatives**

During this academic year, nearly 15 workshops were conducted with teachers and students from various CUBE centres, in Goa, Kerala and Maharashtra. [M. C. Arunan, G. Nagarjuna, M. Kharatmal, J. Advani and CUBE team]
TPD workshops under Vignyan Pratibha Project

As part of the Vignyan Pratibha Project, resource generation camps were held where various activities called learning units (LU’s) were designed for students studying in grade 8 and 9. Workshops were also organized for teachers so as to expose them to these newly developed activities and get their feedback.

The first teacher workshop was organised at HBCSE in September 20 – 24, 2017. A total of 90 teachers participated in the workshop. Of these, 70 teachers were KV teachers, 4 AECS and 16 were JNV teachers and about 80 schools from the three systems were represented in the workshop. The workshop sessions focused on the Vignyan Pratibha LUs.

A workshop for teachers in Kolkata region was organized at SINP, Kolkata in November 13 – 14, 2017. The sessions were conducted jointly by resource persons from HBCSE, SINP, and IISER Kolkata. The workshop was attended by 17 teachers from KV in Kolkata and 8 teachers from AECS in Jaduguda and nearby regions.

The second teacher workshop at HBCSE was organized in January (15 – 18), 2018. A total of 67 teachers participated in the workshop. Of these, 49 were KV teachers, 7 AECS and 11 were JNV teachers and about 55 schools from the three systems were represented in the workshop. Of these 67 teachers, 62 teachers had also attended the first workshop.

In the workshop, feedback from the teachers was obtained about the LUs they had conducted in their schools. Four new LUs were introduced. A new introduction in this workshop was organization of 7 learning-teaching laboratories. In each laboratory, one member from HBCSE conducted a LU with students and the teachers observed the class. After the LU was conducted, there were discussions on various aspects of the teaching and the units.

Consultations, Collaborations and Support to External Institutions

HBCSE members have continued to collaborate, consult and support various external institutions like Rajiv Gandhi Science and Technology Commission and their project on ‘Science and Innovation Activity Centres’, Mumbai Science Teachers’ Association, Royal Society of Chemistry, Hemendra Kothari Foundation, Yashwantrao Chavan Maharashtra Open University, Atomic Energy Educational Society, Centre for Education Innovation and Action Research, TISS and numerous teacher education institutes. HBCSE members have also collaborated with Connected Learning Initiative (CLIX) project, a joint initiative of Tata Trust, Tata Institute of Social Sciences and Massachusetts Institute of Technology.

Bombay Association for Science Education

The Bombay Association for Science Education (BASE) is a voluntary organization run by TIFR scientists in collaboration with school and college teachers from Mumbai region. During the period of this report, BASE jointly with HBCSE organized 4 workshops, in which around 100 teachers participated. The workshops themes were: Assessing our assessment, Assessment and evaluation in teaching, Energy in sciences and Syllabus based experimental workshop. [P. K. Joshi, S. Naik, A. Kanhere, H. Raval, J. Subramanian]}

YCMOU Post Graduate Research Programmes in collaboration with HBCSE

HBCSE is the study centre for Yashwantrao Chavan Maharashtra Open University (YCMOU), Nashik, Post-Graduation Research Programme (PGRP) in Mumbai. The YCMOU offers a two year post-graduation course (M.A, MSc) in Subject Communication and Education Communication through distance mode. The batch of 2015–17 has 58 students and the 2016–18 batch has 55 students. Twelve workshops have been conducted for both batches between April 2017 and March 2018. Besides organising these workshops, students are counseled on various subjects, such as Research Methodology, Instructional System Design and Communication modes in education. HBCSE is involved in the assessment of student assignments and providing help to students in formulating their research problems and in developing their research projects. [S. Chunawala (Coordinator), N. D. Deshmukh, R. Shinde, A. Dolas, A. Kanhere, R. Karandikar, P. Patil, S. Naik]

AEES-HBCSE collaboration

The Atomic Energy Educational Society (AEES) and
HBCSE continue to collaborate in several areas. The junior mathematics and science Olympiads, which is the first stepping stone for the National Olympiads, draw some of the best students of the Atomic Energy Schools from all over the country. The camp was conducted from October 9–12, 2017 at Atomic Energy Junior College [P. K. Joshi, S. Chunawala, R. Vartak, A. Sule, P. De, P. Nawale, V. Ghanekar, S. Mukherjee, A. Kanhere, S. Naik, H. Raval and the academic unit of AEES].

Support to national level assessment

HBCSE members contributed to various prestigious national level assessment and admission processes organised by different external agencies and aimed at higher secondary students. Details of these cannot be listed for the reasons of confidentiality.

Academic support and collaborations with other institutes and organizations

HBCSE members have also extended academic support to other institutes and organizations. In this endeavour, S. Chandrasekharan was invited to design the cognitive science syllabus for the teacher education program at the Gandhigram Rural University, Dindigul, Tamil Nadu (February – June 2017). He also offered an elective course “Advanced Topics in Cognition”, at IIT Bombay, January – April, 2017. The course was attended by students from educational technology, design, computer science, humanities and biomedical engineering. K. Subramaniam made a presentation to the committee chaired by K. Kasturirangan on the National Education Policy (ICTS, Bengaluru, December 2017). S. Chunawala and A. Sharma were invited to the Department of Education of groups with Special Needs, (DESM), NCERT, Delhi to give their inputs and collaborate on developing guidelines aimed at enabling regular science teachers to include children with visual impairments in science laboratory activities 28–29 November 2017.

K. Subramaniam was invited to be the moderator and S. Naik was invited to be a member for the round table on “Effective pedagogy for Mathematics”, Bonjour India – The Future Tour: Mathematics & IT, Indo-French scientific collaboration held at Chennai Mathematical Institute, Chennai (February 1–2, 2018). R. B. Khaparde was invited to chair the oral presentation session on Physics Education during LAPT National Convention 2017 and National Symposium on Recent Trends in Physics at different scales, at Gurukul Kangri Vishwavidyalaya, Haridwar (October 30, 2017). K. K. Mishra was invited as a Subject Expert to the International Conference on Language and Literature in the 21st Century, Mumbai, October 2–4, 2017.

S. Chunawala A. Muralidhar, R. Karandikar served as Advisory Board Members, for the One Day Teacher’s Conference “Moving towards a better understanding of the environment”, organized by Navi Mumbai Science Foundation, Vashi (February 17, 2018). S. Bhide was invited to be a resource person for 2 workshops “Strengthening of Maharashtra Vidya Pradhikaran Subject Resource Group” conducted by Ignus Pahal in collaboration with UNICEF and Maharashtra Academic Authority (Pune, August 2–5, 2017; Sangli, July 4–7, 2017).

HBCSE members actively participated in various capacities (reviewers, chairs, chief guest, project guide) in academic and school events. A. Muralidhar and H. Raval were invited to Atomic Energy Junior College for evaluating science/environment and mathematics projects respectively (April 21, 2017); A. Muralidhar was invited to be an evaluator for science drawings, in an independent project by M. Vaz (April 10, 2017); N. D. Deshmukh was invited to be an evaluator for an essay competition organized by Nehru Science Centre, Mumbai, on ‘From waste to profit through Reduce, reuse and recycle’; V. C. Sonawane was invited to be a jury member for National Children Science Congress 2017 at Government College of Education, Panvel (November 16, 2017).

Royal Society of Chemistry (RSC, UK)

As part of Yusuf Hamied Inspirational Chemistry programme, Royal Society of Chemistry (RSC, UK) has been conducting teacher training for chemistry teachers teaching at secondary level since 2015. HBCSE is responsible for evaluation of this programme and the work for the same was initiated in January 2018. The assessment involves observations of training programmes, visit to schools for classroom observations, interviews with teacher developers and teacher participants, etc. The assessment will be primarily done for the programme conducted for Government schools in states of Karnataka, Kerala and Maharashtra. [S. Ladage. S. Chunawala, V. D. Lale, H. George, R. Bhujbalrao].
Consultancy and collaboration with Timor-Leste National Commission

A project to assess the impact of massive curricular reforms at the school level that were implemented in the young country of Timor-Leste was taken up as a consultancy from the Timor-Leste National Commission for UNESCO through its subdivision of SESIM – The Center for the Study of Science and Mathematics. Questionnaires for teachers and students and the template for data entry were designed. The questionnaire was administered by members of the SESIM team, to a sample of 5920 students (in Grades 7, 8, and 9) and 222 teachers belonging to 70 schools randomly selected from 13 municipalities. Data obtained from the questionnaires was analyzed by us for students and teachers and the report titled “Assessing teachers’ and students’ response to implementation of prātika and its impact in Timor-Leste” was submitted to UNSECO. [J. Vijapurkar, S. Patil, A. Sawant, N. Bagban]

Visitors and student interns at HBCSE

As part of our collaboration with academic institutes, HBCSE had numerous visitors and interns this academic year, during which they either carried out small projects in their area of interest or gave talks and/or offered short courses. Visitors included faculty members from various national and international institutes who offered graduate/short courses at HBCSE. These include D. Chakraverty (Washington State University Spokane), A. Bardapurkar and A. Madan (Azim Premji University, Bengaluru). S. Raje (Towson University, USA), a Fulbright-Nehru Scholar visited HBCSE during July – September 2017 and December 15, 2017 – January 8, 2018, and offered graduate courses during her visit.

Visitors to the centre also included members from organizations like Manav Navnirman Sankalp Charitable Trust (June 1 and August 21, 2017), Indian Statistical Institute, Kolkata (July 5–8, 2017), Garhi Resource Centre (M.P), Hemendra Kohari Foundation (July 9–12, 2017), Centre for Excellence in Basic Sciences, Mumbai (July 26, 2017), IBM members from Finland, Italy, USA, Switzerland, Australia and Spain (November 1, 2017), Illinois University (January 7, 2018), teachers from M-Power study centres of Bhim Nagar, Indra Nagar, Jai Ambe Nagar, Vishnu Nagar, Deonar Colony (February 9, 2018), and Gurukul School Pune (March 15, 2018). Several members such

Vidyut, B. Abbas, V. Bhat, N. Sharma, P. Patil, S. Matri, did short term visitorships/consultancies at HBCSE.

Students/interns from the following institutes visited HBCSE for durations ranging from 1 to 3 months: Tata Institute of Social Sciences (Hyderabad), Wilson College (Mumbai), Thadomal Shahani Engineering College Mumbai, SNDT College, BITS Pilani Goa.

Jean Uwamahoro (Senior Lecturer) and Florien Nsanganwimana (Lecturer & Post-doctoral fellow) from University of Rwanda–College of Education, African Center of Excellence for Innovative Teaching and Learning Mathematics and Science, visited HBCSE from January 2–16, 2018. They attended epiSTEME7 conference and interacted with research scholars and faculty members during their visit.

HBCSE also had student visits from the following schools, institutes and colleges: Cathedral and John Cannon School, Mumbai (April 17, 2017), 35 differently-abled students from Vidyanvahini, Pune (June 1, 2017), University of Mumbai (June 16, 2017), Kendriya Vidyalayas, Jawahar Navodayas, Atomic Energy Central Schools (July 31, 2017), Acton-Boxborough Regional High School, Acton, Massachusetts, USA (August 2–18, 2017), Mithibai College (September 12, 2017), Sagar Public School, Bhopal (November 1, 2017), Tilak College (January 1–5, 2018), Doodhsagar Mahavidyalaya, Kolhapur (February 5, 2018), St. Xaviers College (February 7, 2018).

MSTA– Dr. Homi Bhabha Young Scientists Camp

Since last 7 years, HBCSE has been organising enrichment camps in collaboration with Mumbai Science Teacher Association (MSTA) for Dr Homi Bhabha Young Scientist Awardees. The awardees are at two levels, students studying in class 6 and class 9 from schools that have English or Marathi as the language of teaching-learning. This year the camp for class 6 was organized on April 17–18, 2017 and was attended by 115 participants. The camp for class 9 students was organized on April 20–21, 2017 and was attended by 80 students. These camps are aimed at providing students with exposure to topics that may not necessarily be directly part of school syllabi, but which may spark curiosity and interest in science. Besides, students are also provided with opportunities to participate in hands-on laboratory activities and experiments. [K. Subramaniam, S. Chunawala, V. D. Lale, N. D.
Homi Bhabha Centre for Science Education, Mumbai


RGSTC– Science and Innovation Activity Centres (SIAC) Project

HBCSE is involved in setting up Science and Innovation Activity Centres (SIACs) in Maharashtra. This collaborative project involving HBCSE, the Nehru Science Centre, Mumbai, Bharatiya Vidya Bhavan's Muktangan Exploratory Science Centre, Pune and Vigyan Ashram, Pabal is funded by the Rajiv Gandhi Science and Technology Commission, Government of Maharashtra. A workshop on ‘Setting Sustainable Goals, Resources and Practices for Science and Innovation Activity Centers (SIAC) proposed in Maharashtra’ was organized at HBCSE, from May 2–4, 2017. The workshop’s objective was to help the institutions to form detailed project proposals by setting sustainable goals, resources and practices for Science and Innovation Activity Centers proposed in Maharashtra. [N. D. Deshmukh (Coordinator)]

CUBE meetings, interactions and collaborations

The Collaboratively Understanding Biology Education (CUBE) project expanded to several new nodes across the country. CUBE members successfully established a lab at M-Ward learning centre, Deonar Colony by regular visits twice a week on Thursday and Saturdays. The lab has initiated the exploration of new model systems: creating a butterfly garden and dragon fly mapping, bee mapping, in collaboration with Delhi and Konkan cubists.

CUBE facilitated a Lecture-cum-workshop at IIT Bombay in collaboration with Manu Prakash from Prakash Lab, and Deepak Moddi from NIRMH, for introducing Foldscope, to 50 participants (IIT Bombay, August 29, 2017). Rajya Sabha TV members visited CUBE lab, HBCSE to cover work done in CUBE lab, November 7, 2017. CUBE-CURE Kishore Bharati Locality Lab network programme was initiated in various parts of India, June 2017.

CUBE members presented papers and posters on Drosophila: A model system to study olfactory response, Horizontal gene transfer in rotifers, Regeneration of snail tentacle & restoration of olfactory senses and Regeneration of ventral nerve cord in earthworm, Learning & memory in drosophila larvae in various national seminars and conferences like National Seminar on Innovative Approaches in Biosciences, at Kanoria college, Jaipur on December 15, 2017; Developmental Biology Conference, IISER Pune (June 26–28, 2017); Indian Academy of Neurosciences Conference in Cuttack, Orissa. [Naguarjuna G., M. C. Arunan, M. Kharatmal, J. Advani]

Science Popularisation

HBCSE, over the years, has developed a variety of popular science materials and has aimed at disseminating them to the masses of the country to improve scientific literacy and inculcate scientific temper among its people. During the period of this report, HBCSE staff members contributed articles, gave popular science talks, and featured in radio and TV programs as an integral part of its science popularisation and outreach efforts. Expository articles were published by its staff in the leading national science and technology periodicals of the country.

Visits to HBCSE

HBCSE receives a number of visitors to its laboratories and facilities throughout the year. Visitors include students and teachers from various schools and colleges. Pre-service teachers from B.Ed & D.Ed colleges and teacher-educators also visited HBCSE. Children from some non-governmental organizations (NGOs) from Mumbai region also visited HBCSE. More than 650 visitors visited HBCSE during the period of this report. Students and teachers interact with staff members and take guidance for their school science projects. Some of these students appear for prestigious competitions such as ‘Homi Bhabha Young Scientists Award’ examination. During their visit to HBCSE, school students mostly visited integrated laboratory (IL), but some college students visited Olympiad Laboratories as HBCSE is a nodal centre of the Government of India for Olympiad programs in the country. [V. C. Sonawane (Coordinator), K.T. Hambir, P. Monteiro, M. Pawar]

National Science Day 2018

As in every year, the National Science Day (NSD) was celebrated at the Centre by having an Open House on
February 28, 2018. NSD witnessed over 1700 visitors which included students, teachers, teacher educators, and parents. Some of the main attractions of the NSD were Liquid Nitrogen show, Glass blowing techniques, Rocket science, Computer Corner, Botanical Garden tour, Design & Technology activities, and E-learning portal in Hindi. Lecture and presentation session on solid waste management by CUBE on Simple Model System, was also one of the main attractions. The resource students gave interesting demonstrations on science exhibits related to general science, biology, physics, and mathematics. The charts prepared by teacher student volunteers were also displayed on the occasion. The Centre’s books and materials, as well as publications, resources, toys and posters of other organizations were displayed and kept for sale. [V. C. Sonawane, (Coordinator), and all HBCSE staff members]

Additionally, a contest titled “Innovative teaching-learning practices in the classroom” in collaboration with Pillai College of Education and Research, New Panvel, was organized as part of National Science Day 2018 celebrations. [S. Chunawala, R. Sawant].

Science Popularisation at GMRT, Pune

HBCSE participated in the National Science Day program held at Giant Metrewave Radio Telescope (GMRT), Pune. GMRT organized a two-day program on February 29 and March 1, 2018. HBCSE took active part in the program and put up many gadgets, working models and exhibits. Members also demonstrated an interesting activity on measurement of Total Dissolved Solutes (TDS) in water and testing of water quality. Hundreds of visitors visited HBCSE stall. [V. C. Sonawane (Coordinator), A. Gupta, B. Thube].

Science Popularisation at TIFR Colaba Campus

HBCSE took active part in the TIFR Founder’s Day program held at its main campus in Navy Nagar, Colaba, on October 27, 2017. HBCSE had put up some interesting hands-on experiments and demonstrations on working of gadgets. Hundreds of students, teachers, and parents from Mumbai region visited the stall. [V. C. Sonawane (Coordinator), V. Pawar, K.T. Hambir]. HBCSE members also delivered talks in TIFR’s public outreach initiative “Chai and Why?”. [D. Dutta, H. Raval, C. Navare]

Outreach programmes

As part of HBCSE’s outreach efforts, members participated in the National Children Science Congress (NCSC) held at Gandhinagar, Gujarat, from 27 to 31 December 2017. The focal theme of the program was Science, Technology & Innovation for Sustainable Development. The NCSC is an ideal and innovative program for children to inspire, empower and expand their minds to world. It is a flagship programme of department of science & technology, government of India. HBCSE staff members put up an exhibition on activity-based learning where students could see microscopic species in water. Some hands-on activities on electricity and magnetism were also put up there in the programme. [A. Gupta (Coordinator), V. C. Sonawane, H. Raval, H. Agrawal, K. Subramanian, B. Thube].

Additionally, CUBE lab set up demonstration stalls and had presentations on fruit fly trapping, mosquito mapping and tree mapping, at Samta Hindi Vidyalya, Turbhe, Navi-Mumbai (October 15, 2017), where over 100 students participated.

A two day science enrichment programme for students of class 9 from the Palghar district was organised by Chinmaya Vidyalaya, Tarapur. This programme focused on activity based and hands on science and took place from April 25–26, 2017 at Tarapur. [V. C. Sonawane (Programme Coordinator), K. T Hambir, N. D. Deshmukh, T. Adangale, R. Shinde, P. Nawale, N. Sonawane]

Hindi Divas Programme

Rajbhasha Committee of HBCSE organized competitions for its staff members on the occasion of Hindi Divas. Essay Writing and Hindi Gyan competitions were conducted. The winners were given cash prizes on the Hindi Divas function at HBCSE, September 14, 2017. Rajbhasha Committee also invited Prof. Ramji Tiwari, an eminent scholar, and former Head, Department of Hindi, University of Mumbai, for a talk. [K. K. Mishra, M. Banne, D. Mishra, A. Jadhav]
Director), A. P. Sule, R. R. Vartak, J. Vijapurkar

Scientific Staff

Visiting Fellows

Research Scholars

PhD Students (external)

M. Phil Student
K. Mishra

INSA Senior Scientist
S. M. Roy

Raja Ramanna Fellow
H. C. Pradhan, A. K. Ray

Visiting Faculty (Fulbright Nehru Grant)
S. Raje

Homi Bhabha Fellow (Homi Bhabha Fellowship)
G. D. Kaur

Research Associate under Raja Ramanna Fellow
G. Wagle

Administration

Technical
V. P. Ahire, S. S. Chavan K. T. Hambir, V. C. Jacob, H. H. Rane, N. Y. Tribhuwan

Auxiliary
Consultants
C. Joshi, V. Katdare

National and International Involvement

S. Chandrasekharan
1. Member, Programme Committee, 24th International Conference on Computers and Education, Christ Church, New Zealand
3. Member, Committee which revised the Ph.D. course work syllabus (Cognitive Science for teacher education) for Department of Education, Gandhigram Rural Institute, July 12–13, 2017

S. Chunawala
2. Executive Council Member, Peoples Council of Education, 2015–2018
3. Member, Departmental Advisory Board (DAB), Department of Gender Studies, NCERT
4. Member, Departmental Advisory Board (DAB), Department of Education in Science and Mathematics, NCERT
5. Member, Board of University Teaching and Research, YCMOU
6. Member, Board of Studies, SNDT University, Marine Lines, Mumbai
7. Member, Local Management Committee, K. J. Somaiya Comprehensive College of Education, Training and Research
9. Organizing Committee Member and Reviewer for National level Researcher’s Meet 2017, University of Mumbai
10. Member, Advisory Board Committee, Teachers’ Conference on “Moving towards a better understanding of the environment”, Navi Mumbai Science Foundation, Vashi, February 2018

N. D. Deshmukh
1. Executive Member, Asian Association for Biology Education
2. Executive Member, Indian Ocean Comparative Education Society and
3. Member, Executive Committee, IOCES conference, for 2015 – 2019
4. Member, Editorial Board, Asian Journal of Biology Education
5. Nominated Executive Member, National Association for Research in Science Teaching (NARST)- Linking Science Educators Program (LSEP)
6. Mentor, Inaugural Southeast Asia Science Education Research School, at Institute for the Promotion of Teaching Science and Technology (IPST), Bangkok, Thailand

P. K. Joshi
President, International Junior Science Olympiad for the period 2015 – 2018

R. Karandikar
Member, Advisory Board Committee, Teachers’ Conference on “Moving towards a better understanding of the environment”, Navi Mumbai Science Foundation, Vashi, February 2018

R. Khaparde
1. Visiting faculty member, Ashoka University, Sonepat, Haryana
2. Member, Editorial board, Physics Education, an e-journal published by IAPT
3. Member, Advisory Committee, DBT Star College Scheme for B. N. Bandodkar College, Thane
4. Member, Board of Studies in Physics, Ruia College, Mumbai
5. Member, Executive Council of TIFR Alumni Association

S. Ladage
1. National Coordinator, National Initiative on Undergraduate Science (NIUS) programme
2. Member, Editorial Advisory Board, Journal of Chemical Education (JCE), American Chemical Society, January 2017–present
3. Member, International Steering Committee (ISC) for International Chemistry Olympiad (IChO), 2016 – July 2017
4. Member, Subject Board, Department of Chemistry, Ruia College, Mumbai, July 2017–present
5. Convener, epiSTEME 7 International Conference, January 2018

K. K. Mashood
Member, Committee on International Physics Education, American Association of Physics Teachers (AAPT), 2018 – present

A. Mazumdar
1. National Coordinator, Science Olympiads in India
2. Member, National Steering Committee for Science and Astronomy Olympiads
3. Member, Board of Studies (Physics), Fergusson College (Autonomous), Pune

K. K. Mishra
1. Member, National Academy of Sciences, India
2. Member, Executive Council, Lok Vigyan Parishad, Delhi
3. Member, Editorial Committee, Vigyan Aapke Liye, a quarterly national magazine on popular science and environment
4. Member, Vigyan Parishad Prayag, Allahabad
5. Joint Secretary, Peoples’ Council of Education, Allahabad
6. Member, Advisory Board, Vigyan-Ganga (a science magazine by Banaras Hindu University), Varanasi
7. Member, Advisory Board, Technical Today (a national science and technology magazine by Mewar University)
8. Member, Editorial Board, and Referee for Vigyan Prakash (a quarterly Hindi journal of research in science brought out by Lok Vigyan Parishad, Delhi and World Hindi Foundation), NY, USA
9. Member, Hindi Vigyan Sahitya Parishad, BARC, Mumbai
10. Member, Indian Nuclear Society, Mumbai

A. Muralidhar
Member, Advisory Board Committee, Teachers’ Conference on “Moving towards a better understanding of the environment”, Navi Mumbai Science Foundation, Vashi, February 2018

Visits

M. C Arunan
1. Several colleges in Kerala (Met 45 students and teachers from Cochin college, St. Peters college and Bharat Mata college), Kochi, March 16, 2018
2. Dyal Singh college & ANDC college, Delhi

G. Date
1. 1st Annual School on Grassroots Innovation, National Institute of Advanced Studies (NIAS), Bengaluru, January 10-18, 2018
2. 20th Conference of the Society for Philosophy and Technology, Technische Universität Darmstadt, Germany, June 14-17, 2017

D. Dutta
1. Presentation of research and discussion with Prof. Raymond Young’s lab, University of Michigan, Ann Arbor, March 11–15, 2018

S. Naik
1. Founder Member and Treasurer, Mathematics Teachers’ Association, 2018 – present
2. Nominated member, Women’s Cell of Nehru Science Centre, Mumbai, 2017 – present
4. Member, Academic Advisory Committee, Navi Mumbai Science Foundation for the period, 2017 – 18

S. Narvekar
Treasurer (West Zone), Association of Chemistry Teachers (ACT), January 2017 – 2019

K. Subramaniam
1. Member (ex-officio), Governing Council, Atomic Energy Education Society
2. Country representative for India, International Commission for Mathematics Instruction
3. Member, Journal Editorial board, Contemporary Education Dialogue
4. Member, Journal Editorial board, At Right Angles
5. Member, Advisory board, Information Age Publishing: International Sourcebooks in Mathematics and Science Education

A. Sule
1. General Secretary, International Olympiad on Astronomy and Astrophysics, January 1, 2017 – December 31, 2021
2. Member of Public Outreach and Education Committee of Astronomical Society of India

J. Vijapurkar
Invited reviewer, Review of Education (Wiley)

S. Ladage
National Conference for Advanced POGIL Practitioners,

R. Khaparde
Center for the Advancement of STEM Teaching and Learning, Dublin City University, Dublin (visited) and participated in the GIREP-EPEC-ICPE Conference at Dublin City University, Dublin, Ireland, July 2–15, 2017.

S. Ladage
National Conference for Advanced POGIL Practitioners,

K. K. Mishra
“Language and Literature”, 3-day International Conference organized by Hindustani Prachar Sabha, Mumbai, October 2–4, 2017

S. Naik and K. Subramaniam

G. Singh
Annual National Science Conference, Marathi Vidnyan Parishad (as part of Cognic Zoom team, to setup exhibition on Cognic Zoom at Kudal), December 16–18, 2017

K. Subramaniam

Invited Talks

S. Chunawala
1. Ethics in education research (Review Talk). Workshop on understanding research methodology in social sciences for SC/ST students, jointly organized by Department of Education, University of Mumbai and the Indian Council of Social Science Research (Western Regional Centre), June 8, 2017
2. Role of education in women’s empowerment. National Conference on ‘Paradigm Shift in Women Empowerment’ (Inaugural Keynote address), B.Ed. College for Women, Mumbai, March 10, 2018
3. An inclusive science and technology education curriculum at school level. State Level Seminar on “Contribution of Women in Nation Building: Creating the Momentum for Social Inclusion” (Keynote address), The Lords Universal College for Education, Mumbai, March 10, 2018
4. Strategies for effective classroom interaction. National Seminar on “Dynamics of Effective Classroom Teaching” (Keynote address), Thakur Shyamnarayan College of Education and Research, Mumbai, March 16, 2018

A. Muralidhar
Environment education at HBCSE: A review (Review Talk) in One day Teacher’s Conference “Moving towards a better understanding of the environment”, organized by Navi Mumbai Science Foundation, Vashi, February 17, 2018

S. Naik
Professional development of mathematics teachers: What do we learn from research? Symposium on Teacher Education in India: What are we Learning from Research? (Plenary address), Centre for Education Innovation and Action Research, Tata Institute of Social Sciences, Mumbai, August 21, 2017.

K. Subramaniam
2. The qualitative paradigm shift in social research (Inaugural Keynote address). Workshop on understanding research methodology in social sciences for SC/ST students, jointly organized by Department of Education, University of Mumbai and the Indian Council of Social Science Research (Western Regional Centre), June 8, 2017.
3. Engaging with teachers’ knowledge (Plenary address as Zenex Foundation International Speaker). Annual Conference of Association for Mathematics Education of South Africa, Nelson Mandela University, Port Elizabeth, South Africa, July 3–7, 2017

A. Sule
1. International Symposium on Education in Astronomy and Astrobiology, Utrecht, Netherlands, July 2017
2. Haus der Astronomie, Max Planck Institute for Astronomy, Heidelberg, Germany, July 2017
3. Leibniz Institute for Astrophysics, Potsdam, Germany, July 2017
4. Price of Songkla University, Phuket, Thailand, September 30–October 3, 2017

A. Sule and P. Ranadive
1. IAU Symposium on Solar Physics (IAUS340), M. P. Birla Institute, Jaipur, February 2018
2. Department of School Education, Govt. of J&K in connection with a workshop on observational Astronomy Srinagar (on invitation), March 2018

J. Vijapurkar
1. An empirical approach to curriculum development (Review talk). epiSTEME7: Seventh International Conference to Review Research on Science, Technology and Mathematics Education, HBCSE, January 6, 2018
Conferences Organized by the Centre

Why ‘Whisper’ when we can talk? An awareness programme on the occasion of ‘World Menstrual Hygiene Day’
HBCSE, June 2, 2017

Vigyan Pratibha Launch
HBCSE, July 31, 2017

Essay Writing and Hindi Gyan competitions organized by the Rajbhasha Committee of HBCSE
HBCSE, September 7–8, 2017

Hindi Divas Function
HBCSE, September 14, 2017

Sixteenth V. G. Kulkarni Memorial Lecture
HBCSE, September 21, 2017

Founder’s Day Celebration
HBCSE, October 30, 2017

Homi Bhabha Award in Science Education – 2016
HBCSE, November 3, 2017

Infosys Award Function
HBCSE, December 22, 2017

Workshops for students

1. Dr. Homi Bhabha Young Scientist Enrichment Camp 2017, for 115 students of class 6 (HBCSE, April 17–18, 2017); for 80 students of class 9 (HBCSE, April 20–21, 2017)
2. Orientation-cum-Selection Camps (OCSC) 2017 for students and several resource persons, OCSC Astronomy (HBCSE, April 22 – May 8, 2017); OCSC Junior Science (HBCSE, May 1 –31, 2017); OCSC Chemistry (HBCSE, May 23– June 3, 2017); OCSC Physics (HBCSE, May 27–June 9, 2017); OCSC Biology (HBCSE, June 1–10, 2017)
3. Two days activity based science experiments and demonstration workshop, for around 90 students of grade 9, Chinmaya High School (Tarapur, April 25–26, 2017)
4. One month summer camp for about 15 students of grade 5, from Nutan Vidya Mandir school (HBCSE, May 1–31, 2017)
5. One-day workshop on ‘Fun with mathematics!’, for 19 students, summertime workshop by TIFR outreach team (Prithv Theater, Mumbai, May 16, 2017)
6. One day workshop on ‘Learning through experiments’ for 50 students from Saher an NGO based in Mumbai (HBCSE, May 24, 2017)
7. NIUS exposure cum enrichment camp, in Physics for 74 students (HBCSE, June 13–28, 2017); in Biology camp for 41 students (HBCSE, October 30– November 3, 2017); in Chemistry for 51 undergraduate students (HBCSE, December 23–29, 2017)
9. Workshop on science experiments for 60 INSPIRE students of Class 11 and 12 at A. N. College (Patna, September 17–18, 2017)
10. Six-day Workshop on “Illustrator and Indesign”, for 25 students,

National Seminar on Pedagogical and Assessment Issues, Guru Ghasidas Vishwavidyalya Central University, Bilaspur, February 23, 2018

International Conference epiSTEME–7
HBCSE, January 5–8, 2018

CUBE Winter Meet
HBCSE, February 11, 2018

National Science Day 2018
HBCSE, February 28, 2018

Annual Research Meet 2017
HBCSE, March 6–8, 2018

International Women’s Day Celebration: Screening of the movie “Un-limited Girls”
HBCSE, March 12–13, 2018

Asian Pacific Mathematics Olympiad Examination
March 13, 2018

Madhava Mathematical Competition Award Function
HBCSE, March 20, 2018

Mathematics Teachers’ Association Founding Meeting
HBCSE, March 20, 2018
undergraduate students, as part of their Bachelor of Design course. (NMIMS School of Design, October 6–12, 2017)

11. Developing mathematics lab in schools, for 8 MA in Elementary Education students from TISS Mumbai and TISS Hyderabad (HBCSE, November 1, 2017)

12. Hands-on minds-on mathematics workshop for students from Royal Girls high school, Mumbai (HBCSE, November 22, 2017); for 150 secondary school students, Frontiers of Science 2017 (TIFR, November 26, 2017); for secondary school students, National Science Day 2018 (TIFR, February 25, 2018)

13. Observing and documenting bird behaviours, with 8 middle school students (M-ward Community Centre, Govandi, January 13, 2018)


**Collaborative Undergraduate Biology Education (CUBE) Workshops and Meets**

15. CUBE Pre-Summer Workshop on designing assays, experimental analysis, introduction of using simple model systems, for 20 participants from CHM College, Elphinstone College, Mumbai and MSU Baroda, Gujarat (HBCSE, April 4–30, 2017); Summer workshop for 25 participants from Ranchi, Chennai and Gujarat CUBE centres (HBCSE, May 1–31, 2017)

16. CUBE workshop on learning and memory studies with drosophila larvae, isolation of nematods, learning and memory with C. elegans, etc. for 10 undergraduate students from Elphinstone College, Acharya Narendra Dev College, Delhi and IIS University, Jaipur (HBCSE, June 1–15, 2017)

17. CUBE workshop on simple model based system for 50 blind school students organised by Makerwala Dhamtari (Dhamtari, June 29, 2017)

18. A four day workshop on (i) assessment of distance by different groups of students; (ii) face recognition and its connection to ethnicity (HBCSE, July 5–8, 2017)

19. CUBE workshop for 10–12 students and teachers at BITS-Pilani, Goa (Goa, July 10–12, 2017)

20. CUBE Royal College Workshop on “Initiating model organisms — Fruitfly, Moina, Pagalapos, Earthworm” for 30 undergraduate students and 2 teachers (HBCSE, August 28, 2017)

21. CUBE M-Ward Workshop on “Introducing butterfly mapping and fruitfly activity pattern (circadian rhythm)”, in collaboration with TISS, for around 50 college and school students (M-Power Centre, Deonar, held on Thursdays & Saturdays from September 2017 onwards)

22. CUBE Diwali Workshop (HBCSE, October 16–30, 2017)

23. One day CUBE workshop for around 30 students/teachers of Indian Women Scientists Association (IWSA) (Navi Mumbai, November 4, 2017)

24. Two days workshop on activities such as Fruit fly trapping, Moina culturing, Earthworm collection, Mango mapping, Butterfly mapping for around 200 students (Dalwai High school, Chipilunk, November 14–15, 2017)

25. One day workshop to develop a hub with Moina model system for approximately 50–60 students (Sanquelim College, Goa, December 7, 2017)

26. CUBE Christmas Workshop for 60 students of local colleges such as CHM College, VES College, KGP College, Somaiya College, SIES College, Elphinstone College (HBCSE, December 23, 2017 – January 2, 2018)

27. Extended CUBE Winter Workshop, for 10 students from Tilak College (HBCSE, January 5–15, 2018)

28. Lecture-cum-workshop on Mango phenology mapping and fruit fly trapping studies, simple model systems, for 70 students and 10 teachers, MGM School, Varkala (Kerala, March 16–17, 2018)

**Workshops for Pre/ In-Service Teachers**

1. Resource Generation Camp for Astronomy Olympiad (HBCSE, for 20 teachers, April 1–2, 2017; for 16 teachers, November 4–5, 2017; for 20 teachers, January 4, 2018; for 15 teachers, March 17–18, 2018)

2. Resource Generation Camps (RGCs) for Chemistry Olympiad (HBCSE, April 1–2, and 29–30, 2017); for 15 teachers (HBCSE, August 28–31, 2017); for 5 teachers (University of Pune, October 15, 2017); for 9 teachers (HBCSE, October 29–31, 2017); for 13 teachers (HBCSE, November 27–31, 2017); for 4 teachers (HBCSE, December 3, 2017); for 10 teachers (HBCSE, January 31 to February 12, 2018); for 14 teachers, in collaboration with the Association of Chemistry Teachers (ACT) (HBCSE, March 9–11, 2018)


5. Resource Generation Camp for Biology Olympiad for the following topics Cell Biology, Plant Sciences, Animal Sciences, Genetics & Evolution and Ethology &
6. Resource Generation Camp for Physics Olympiad (HBCSE, for 13 teachers, October 8–10, 2017; for 2 teachers and 8 teachers respectively, December 19–21, 2017 and February 5–9, 2018; for 10 teachers (Theory) and 11 teachers (Experiments), March 5–9 and March 12–23, 2018 respectively)


8. Two half day workshops on ‘Measurement in middle school’, for Muktangan Teachers (June 7–8, 2017)

9. One day hands-on science and mathematics workshop for 7 primary school Mathematics and science teachers (voluntarily participants) from nearby schools in Trombay (HBCSE, June 20, 2017)

10. Workshop on mathematical knowledge for teaching for 30 primary and middle school teachers organized by HBCSE in collaboration with Muktangan (HBCSE, July 7–8, 2017)

11. Workshop on “Energy in sciences”, in association with Bombay Association for Science Education (BASE), for 51 participants, Nehru Science Centre (Mumbai, July 8, 2017)


15. Digital literacy workshop for 27 undergraduate teachers, collaboratively organised by NUSSD, TISS ( Maulana Azad University Jodhpur, July 30, 2017)


17. Two-days’ workshop on “Integrating concepts in the undergraduate biology laboratory course”, for 42 college teachers from Maharashtra (HBCSE, September 7–8, 2017)

18. Workshop on “Role of assessment and evaluation in teaching”, in collaboration with BASE, for 23 teachers (HBCSE, September 16, 2017)

19. Five day residential “Vigyan Pratibha Teachers’ Workshop”, for around 90 teachers from Kendriya Vidyalaya (KV), Jawahar Navodaya Vidyalaya (JNV) and Atomic Energy Central School (AECS) (HBCSE, September 20–24, 2017); Four day residential workshop for around 60 teachers from KV, JNV and AECS (HBCSE, January 15–18, 2018)


21. Three day Vigny Pratibha workshop for teachers in collaboration with Saha Institute of Nuclear Physics (Kolkata, November 13–15, 2017)

22. Developing mathematics lab in schools, for 16 teachers from Nashik Education Society, Nashik (HBCSE, November 23, 2017)

23. One day hands-on training workshop on Organic Electronics (HBCSE, December 6, 2017)


25. One-day programme as part of the refresher course on Foundations of Physical Chemistry and its Applications, in collaboration with Indian Women Scientists’ Association, for 25 chemistry teachers at undergraduate / post-graduate level (HBCSE, December 18, 2017)

26. Teacher training program on Junior Science Olympiad for 22 teachers (Sawantwadi, December 18–20, 2017); and for 16 teachers (Kankavali, December 21–23, 2017)

27. Three days’ workshop on “Active learning in optics and photonics (ALOP) and experimental problem solving in physics” for 36 teacher participants (HBCSE, January 10–12, 2018)


29. One day teachers training on “Activity based learning”, for 30 B.Ed students from various colleges in Mumbai (HBCSE, February 26, 2018)

Workshops for teacher educators/ education officers/ resource persons

1. Development of resources workshop for Cognic Zoom (HBCSE, April 3–4, 2017)

2. RGSTCs Mentor Workshop on Design and Planning Activities for Stakeholders (HBCSE, May 2–4, 2017)

3. Workshop on Open Educational Resources for 15 junior college teachers, 10 participants from TISS, 3
participants from Azim Premji Foundation, collaboratively organised by SCERT, Chattisgarh and TISS (Raipur, June 27–30, 2017)


5. Vigyan Pratibha Resource Generation camp, for around 50 high school and undergraduate (science and mathematics) university teachers (HBCSE, August 22–24, 2017); for Biology, 7 external resource persons (HBCSE, March 9–11, 2018); for Physics, 5 external resource persons (HBCSE, March 9–11, 2018); for Mathematics, 6 external resource persons (HBCSE, March 10–12, 2018); for Chemistry, 4 external resource persons (HBCSE, March 15–17, 2018); for Local Context, 4 external resource persons (HBCSE, March 16–18, 2018)

6. Gnowledge Lab Open Educational Resources (OER) advanced training workshop for SCERT, Chhattisgarh, organized in collaboration with CEIAR, TISS (HBCSE, August 28–September 1, 2017)

7. One day workshop on “Development of inventory of conceptual based (involving higher order thinking) multiple choice questions in chemistry and standardization of the same” for 10 teacher participants (HBCSE, September 2, 2017)

8. National Repository of Open Educational Resources (NROER) workshop for capacity building & upgrading NROER platform organized in collaboration with Central Institute of Educational Technology for 30 participants (NCERT Delhi, January 31–February 2, 2018); for 25 participants (HBCSE, Mumbai, March 26–30, 2018)

9. Three days residential workshop on “Teaching teachers using artefacts of teaching”, for around 25 District Subject specialists (mathematics) as selected by SCERT, Haryana (HBCSE, September 2, 2017)

10. Three days residential workshop on “Teaching teachers using activities in science”, for around 25 District Subject specialists (science) as selected by SCERT, Haryana (HBCSE, February 8–10, 2018)

Non-DAE Projects

School of Technology and Computer Science
Agreement Tests on Graphs and Hypergraphs

Agreement tests are a generalization of low degree tests that capture a local-to-global phenomenon, which forms the combinatorial backbone of most PCP constructions. In an agreement test, a function is given by an ensemble of local restrictions. The agreement test checks that the restrictions agree when they overlap, and the main question is whether average agreement of the local pieces implies that there exists a global function that agrees with most local restrictions.

There are very few structures that support agreement tests, essentially either coming from algebraic low degree tests or from direct product tests (and recently also from high dimensional expanders). In this work, we prove a new agreement theorem which extends direct product tests to higher dimensions, analogous to how low degree tests extend linearity testing. As a corollary of our main theorem, we show that an ensemble of small graphs on overlapping sets of vertices can be glued together to one global graph assuming they agree with each other on average.

Our agreement theorem is proven by induction on the dimension (with the dimension 1 case being the direct product test, and dimension 2 being the graph case). A key technical step in our proof is a new hypergraph pruning lemma which allows us to treat dependent events as if they are disjoint, and may be of independent interest.

Beyond the motivation to understand fundamental local-to-global structures, our main theorem is used in a completely new way in a recent paper by the authors for proving a structure theorem for Boolean functions on the $p$-biased hypercube. The idea is to approximate restrictions of the Boolean function on simpler subdomains, and then use the agreement theorem to glue them together to get a single global approximation. [P. Harsha, I. Dinur (Weizmann Institute of Science, Israel) and Y. I. Filmus (Technion, Israel)]

Algebraic Independence Testing Over Finite Fields

A natural problem in algebraic complexity is understanding the notion of algebraic independence. Given a set of input polynomials, can we efficiently check if the set of polynomials are algebraically independent or not? There is a randomised polynomial time algorithm for this problem over characteristic zero fields but there is no known randomized algorithm over finite characteristic fields. The main bottleneck appears to be the failure of the Jacobian criterion. A recent result of Pandey, Saxena and Sinhababu has shown that there is an analogous Jacobian-like criterion over finite characteristic fields but unfortunately it does not directly yield a randomized algorithm. Prerona Chatterjee and Ramprasad Saptharishi are investigating this problem and have partial results towards proving such a randomized algorithm under a suitable conjecture about the structure of polynomials under generic affine transformations. [R. Saptharishi and P. Chatterjee]

Algorithms for Integral Inverse Optimization

In an inverse optimization problem, we are given a set of solutions to a problem, and we wish to determine parameters for the problem so that the set of solutions is optimal. For example, in the inverse shortest path problem, we are given a set of paths in a network, and wish to find costs for the edges of the network so that the given set of paths are the minimum cost paths. Inverse problems find many applications in telecommunications, tomography, and network optimization. These problems have been studied, and algorithms are known for finding such costs. We give algorithms for obtaining integral costs for inverse optimization problems. Integrality is a frequent constraint. For example, in telecommunication networks, the edge lengths must be short integers. In
network tolling, the tolls are multiples of the base currency. Our work gives optimal or nearly-optimal algorithms for a variety of different integral inverse optimization problems, including fundamental problems such as inverse min-cost path, min-cost flow, min-cost bipartite matching, min-cost matroid basis, as well as general inverse polyhedral optimization. [U. Bhaskar, S. Ahmadian, L. Sanita and C. Swamy (University of Waterloo, Canada)]

**Boolean Function Analysis on High-dimensional Expander**

We initiate the study of Boolean function analysis on high-dimensional expanders. We describe an analog of the Fourier expansion and of the Fourier levels on simplicial complexes, and generalize the FKN theorem to high-dimensional expanders.

Our results demonstrate that a high-dimensional expanding complex \( X \) can sometimes serve as a sparse model for the Boolean slice or hypercube, and quite possibly additional results from Boolean function analysis can be carried over to this sparse model. Therefore, this model can be viewed as a derandomization of the Boolean slice, containing \( |X(k)| = O(n) \) points in comparison to \( \binom{n}{k+1} \) points in the \((k+1)\)-slice (which consists of all \( n \)-bit strings with exactly \( k+1 \) ones). [P. Harsha, Y. Dikstein, I. Dinur (Weizmann Institute of Science, Israel) and Y. I. Filmus (Technion, Israel)]

**Bounds on the Distortion of Truthful Cardinal Voting Mechanisms**

A cardinal voting mechanism is one where each voter reports her numeric utility for each candidate. In contrast, in ordinal voting mechanisms, voters merely report their ranking for each candidate. It is known that ordinal voting mechanisms can have large distortion, i.e., the total utility of the candidate selected could be small compared to the best possible. Cardinal voting mechanisms are clearly more expressive than ordinal mechanisms, and thus one hopes that these have better distortion than ordinal mechanisms. Without further restrictions, this is trivially true. A natural restriction on mechanisms is that they must be truthful, so that each voter should be incentivized to report her numeric utilities truthfully, no matter what strategies are adopted by the other voters. We show that under this restriction, the distortion of cardinal mechanisms is almost as bad as that of ordinal mechanisms, and hence the benefits of expressiveness are almost nullified by the truthfulness restriction. We also show a number of related lower bounds, and give a class of mechanisms called hyperspherical mechanisms that are nearly optimal. [U. Bhaskar and A. Ghosh (Indian Institute of Technology, Guwahati)]

**Circuits with Restricted Parse Trees**

Proving lower bounds for non-commutative circuits is a major challenge in the field of algebraic complexity. Although we have a near-complete understanding of a subclass called non-commutative algebraic branching programs, the current techniques do not appear to yield much light for non-commutative circuits. A recent study initiated by Lagarde, Malod and Perifel considered non-commutative circuits with restrictive parse trees. For this model, they proved lower bounds and white-box polynomial identity tests. Anamay Tengse and Ramprasad Saptharishi's work titled “Quasipolynomial Hitting Sets for Circuits with Restricted Parse Trees” extend these results in several fronts - they provide quasipolynomial time blackbox polynomial identity tests for circuits with at most constantly many parse trees, polynomial time blackbox polynomial identity tests if the width of the circuit is bounded by a constant, and also prove separation and depth reduction results for various related classes. [R. Saptharishi and A. Tengse]

**Distance-preserving Subgraphs of Interval Graphs**

In this work distance-preserving and distance-approximating subgraphs of interval graphs were studied. It was shown that interval graphs on \( k \) terminals have \( +1 \) distance-approximating subgraphs with \( O(k) \) branching vertices, and distance-preserving subgraphs with \( O(k \log k) \) branching vertices. Both these bounds were shown to be optimal up to constants. Furthermore, it was shown that there exists an interval graph which provides a separation between branching vertices and branching edges. [J. Radhakrishnan and K. Gajjar]

**Hardness of Equilibrium Computation for 2-player Weighted Congestion Games**

Previously, Milchtaich (Int'l. J. Game Theory, 2013) gave a reduction from finite games to congestion games. This showed that finite games were equivalent to congestion games. However, the reduction required either that each player have her own specific cost
function on each edge, or that players have weights and there exist edges that can only be used by certain players. Both resulted in non-standard congestion games. Further, the cost functions used by Milchtaich were not convex. We modify the construction to show that two-player finite games are equivalent to two-player weighted congestion games with convex quadratic cost functions. This shows that finding a Nash equilibrium in two-player weighted congestion games is PPAD-hard. Our result is tight, since it is known that for linear cost functions, the equilibrium can be computed in polynomial time. [U. Bhaskar and P. R. Lolakapuri]

List Decoding with Double Samplers

We develop the notion of double samplers, first introduced by Dinur and Kaufman, which are samplers with additional combinatorial properties, and whose existence we prove using high dimensional expanders.

We show how double samplers give a generic way of amplifying distance in a way that enables efficient list-decoding. There are many error correcting code constructions that achieve large distance by starting with a base code $C$ with moderate distance, and then amplifying the distance using a sampler, e.g., the ABNNR code construction is such. We show that if the sampler is part of a larger double sampler then the construction has an efficient list-decoding algorithm and the list decoding algorithm is oblivious to the base code $C$ (i.e., it runs the unique decoder for $C$ in a black box way).

Our list-decoding algorithm works as follows: it uses a local voting scheme from which it constructs a unique games constraint graph. The constraint graph is expanding, allowing solutions to be found efficiently, and these solutions are the output of the list decoder. This is a novel use of a unique games algorithm as a subroutine in a decoding procedure, as opposed to the more common situation in which unique games are used for demonstrating hardness results.

Double samplers and high dimensional expanders are akin to pseudorandom objects in their utility, but they greatly exceed random objects in their combinatorial properties. We believe that these objects hold significant potential for coding theoretic constructions and view this work as demonstrating the power of double samplers in this context. [P. Harsha, I. Dinur, I. I. Navon (Weizmann Institute of Science, Israel), T. Kaufman (Bar Ilan, Israel) and A. T. Shma (Tel Aviv University, Israel)]

Low Degree Almost Boolean Functions are Sparse Juntas

Nisan and Szegedy showed that low degree Boolean functions are juntas. Kindler and Safra showed that low degree functions which are almost Boolean are close to juntas. Their result holds with respect to $\mu_p$ for every constant $p$. When $p$ is allowed to be very small, new phenomena emerge. For example, the function $y_1 + \cdots + y_{\varepsilon/p}$ (where $y_i \in \{0,1\}$) is close to Boolean but not close to a junta.

We show that low degree functions which are almost Boolean are close to a new class of functions which we call sparse juntas. Roughly speaking, these are functions which on a random input look like juntas, in the sense that only a finite number of their monomials are non-zero. This extends a result of the second author for the degree 1 case.

As applications of our result, we show that low degree almost Boolean functions must be very biased, and satisfy a large deviation bound.

An interesting aspect of our proof is that it relies on a local-to-global agreement theorem. We cover the $p$-biased hypercube by many smaller dimensional copies of the uniform hypercube, and approximate our function locally via the Kindler–Safra theorem for constant $p$. We then stitch the local approximations together into one global function that is a sparse junta. [P. Harsha, I. Dinur (Weizmann Institute of Science, Israel) and Y. I. Filmus (Technion, Israel)]

Lower Bounds for Data-Structures Via New Simulation Theorems

With collaborators Michal Koucky, Bruno Loff and former Ph.D. student Sagnik Mukhopadhyay, Arkadev has been steadily working on developing simulation theorems that lift relatively more rudimentary query complexity lower bounds to communication complexity lower bounds. In the decision tree setting, the algorithm is charged one unit of cost for accessing/querying an input bit, out of a total of $n$ bits. This is the only source of cost for the algorithm. Thus, for efficiently computing a function $f$, a query/decision-tree algorithm optimizes the amount of queries needed in the worst case. Many lower bounds
are known for this set-up. For example, simple functions like OR, AND and Parity have asymptotically full cost. Consider the set-up of composed function: \((f \circ g)\), a boolean function on \(2nb\) input bits, where \(g\) is a boolean function on \(2b\) bits and \(f\) on \(n\) bits. For such a composed function, there is a natural 2-party communication game. Alice gets \(nb\) input bits and Bob gets the \(nb\) bits, with each of them missing \(b\) bits of input from each of the \(n\) instances of \(g\). Given a decision-tree query algorithm for \(f\), there is a natural communication protocol for Alice and Bob towards solving \((f \circ g)\). Simulate the query algorithm for \(f\), replacing the query of the \(i-th\) input bit of \(f\) with an invocation of the optimal communication protocol to solve the \(i-th\) instance of \(g\). The resulting communication protocol will have cost at most the product of the query cost of \(f\) and the communication cost of \(g\). Determining conditions under which this is an optimal protocol for \((f \circ g)\) is a very important and active area in which Arkadev’s recent research at TIFR has contributed.

While the above considered settings were ones in which Alice and Bob have inputs of comparable size, it is natural to consider situations where they don’t, i.e. one player, say Alice, holds a much larger input of length \(N\) bits compared to what the other, Bob, has of length \(n\). Unlike before, we now allocate different budgets of communication for each player, commensurate with its length of input. Thus, a problem can be non-trivially solved when Alice communicates \(o(N)\) bits AND Bob communicates \(o(n)\) bits. This setting was considered in the seminal work of Miltersen, Nisan, Safra and Wigderson (MNSW) in the nineties to analyze information transfer bottlenecks facing data-structure algorithms that tried to minimize the space used for storing data and the time spent on answering queries simultaneously. In particular, MNSW introduced a technique called the richness method to prove strong lower bounds for deterministic and one-sided randomized protocols. In a recent joint work, Arkadev developed a technique, based on a novel simulation theorem for this setting for a class of functions.

This is the first simulation theorem in the asymmetric setting and interestingly, unlike in the symmetric case, parity decision trees show up. Using this simulation theorem, they were able to show for the first time, that the richness method of MNSW does not in general give tight bounds on the asymmetric complexity of functions. Additionally, this yielded the first strong lower bounds for natural data-structure problems like Vector-Matrix-Vector product problems that are of significant interest. [A. Chattopadhyay, S. Mukhopadhyay and M. Koucky, B. Loff (Charles University, Czech Republic)]

**Lower Bounds for Homogeneous Depth-5 circuits Over Finite Fields**

Recent results in algebraic complexity have presented techniques that are useful for proving lower bounds for shallow circuits. However, all known approaches seem to fail to prove lower bounds for even homogeneous depth-5 circuits. Mrinal Kumar and Ramprasad Saptharishi’s work titled “Exponential Lower Bounds for Homogeneous Depth-5 Circuits over Finite Fields” extends the frontier of understanding by proving exponential lower bounds over any fixed finite field. This introduces a novel evaluation perspective of prior techniques and also tight estimates for projected shifted partial derivatives of some natural polynomial classes. [R. Saptharishi and M. Kumar (Harvard University, USA)].

**On Multilinear Forms: Bias, Correlation and Tensor Rank**

In this work, we prove new relations between the bias of multilinear forms, the correlation between multilinear forms and lower degree polynomials, and the rank of tensors over \(\mathbb{F}_2 = \{0,1\}\). We show the following results for multilinear forms and tensors.

**Correlation bounds**

We show that a random \(d\)-linear form has exponentially low correlation with low-degree polynomials. More precisely, for \(d \ll 2^{o(k)}\), we show that a random \(d\)-linear form \(f(X_1, X_2, \ldots, X_d): (\mathbb{F}_2^k)^d \rightarrow \mathbb{F}_2\) has correlation \(2^{-k(1-o(1))}\) with any polynomial of degree at most \(d/2\).

This result is proved by giving near-optimal bounds on the bias of a random \(d\)-linear form, which is in turn proved by giving near-optimal bounds on the probability that a sum of \(t\) random \(d\)-dimensional rank-1 tensors is identically zero.

**Tensor-rank vs Bias**

We show that if a \(d\)-dimensional tensor has small rank,
then the bias of the associated \( d \)-linear form is large. More precisely, given any \( d \)-dimensional tensor

\[
T: [k] \times \ldots [k] \rightarrow \mathbb{F}_2
\]

d of rank at most \( t \), the bias of the associated \( d \)-linear form

\[
f_T(X_1, \ldots, X_d) = \sum_{(i_1, \ldots, i_d) \in [k]^d} T(i_1, i_2, \ldots, i_d) X_{1,i_1} \cdot X_{1,i_2} \cdots X_{d,i_d}
\]

is at least \( \left( 1 - \frac{1}{2^d-1} \right)^t \).

The above bias vs tensor-rank connection suggests a natural approach to proving nontrivial tensor-rank lower bounds for \( d = 3 \). In particular, we use this approach to give a new proof that the finite field multiplication tensor has tensor rank at least 3.52\( k \), which is the best known rank lower bound for any explicit tensor in three dimensions over \( \mathbb{F}_2 \). [P. Harsha, A. Bhrushundi, S. Kopparty (Rutgers University, USA), P. Hatami (University of Texas at Austin, USA) and M. Kumar (Harvard University, USA)]

**Popular Matchings in Bipartite Graphs**

We considered a generalization of the max-size popular matching problem in bipartite graphs: this is the max-weight popular matching problem where there is also a weight function \( w : E \rightarrow \mathbb{R} \) and the objective is to find a popular matching of largest weight. We showed this is an NP-hard problem and this is so even when \( w(e) \in \{1,2\} \) for every \( e \in E \). When all edge weights are non-negative, a \( \frac{1}{2} \) approximation can be computed in polynomial time. We also showed a fast exponential time algorithm for computing a max-weight popular matching with real edge weights; more precisely, its running time is \( O^*(2^{n/4}) \) in \( G = (A \cup B, E) \) on \( n \) vertices.

We also considered the following problem in a bipartite graph \( G \): given a parameter \( k \), is there a popular matching of size \( k \) in \( G \)? Here \( \min < k < \max \), where \( \min \) and \( \max \) are the sizes of a min-size and a max-size popular matching in \( G \). While there exist simple linear time algorithms to compute min-size and max-size popular matchings in \( G \), we showed it is NP-hard to decide if \( G \) admits a popular matching of size \( k \), for a given parameter \( k \). For any \( \min < k < \max \), we also showed a linear time algorithm to construct a matching of size \( k \) whose unpopularity factor is at most 2. [T. Kavitha]

**The Popular Roommates Problem**

We considered the problem of deciding whether a graph \( G = (V, E) \) with strict preference lists admits a popular matching or not. A matching \( M \) is popular if there is no matching \( M' \) in \( G \) such that the vertices that prefer \( M' \) to \( M \) outnumber those that prefer \( M \) to \( M' \). We showed it is NP-hard to solve the above problem in a general graph.

When the graph is bipartite, popular matchings always exist since a stable matching is a min-size popular matching and stable matchings are always present in a bipartite graph. A simple linear time algorithm is known to compute a max-size popular matching in a bipartite graph. We showed that even in roommates instances that admit stable matchings, it is NP-hard to compute a max-size popular matching.

The linear time algorithm to compute a max-size popular matching in a bipartite graph computes a special matching called a dominant matching. Dominant matchings always exist in a bipartite graph. We showed it is NP-hard to decide if a roommates instance \( G \) admits a dominant matching or not.

We defined a subclass of dominant matchings called strongly dominant matchings and showed a linear time algorithm to solve the strongly dominant matching problem in a general graph. In bipartite graphs, strongly dominant matchings are equivalent to dominant matchings. [T. Kavitha]

**Weights at the Bottom Gates Matter for Depth-2 Threshold Circuits**

In this work, we resolve, among other things, a problem on threshold circuits that has been open since the seminal work of Goldmann, Hastad and Razborov (GHR) from 1992. While techniques of deep learning seem to be revolutionizing the practice of machine learning algorithms, the theory behind it is far from being understood. One impediment to this is the lack of our understanding of the expressive power of threshold circuits, where each gate is a linear threshold function (LTF), or just a half-space. The power of an LTF is derived from the freedom of choosing weights associated with its variables. Indeed, neural network based learning techniques seem to exploit this freedom.
crucially. Yet, GHR showed that in such acyclic depth-2 networks, if the top gate has small weight, then the weights on the bottom gates do not matter much. Every such bottom heavy network could be simulated by a slightly larger network where the bottom gates are light. The problem of understanding if in every depth-2 network one could assume the bottom layer to be light, remained open and was identified repeatedly, by other researchers, as an important one. We solved this problem completely by exhibiting a simple function $f$ that necessitates the bottom layer to be heavy in every small depth-2 threshold circuit computing $f$. [A. Chattopadhyay and N. Mande]

Zero-error List-decoding Capacity of the $q/(q-1)$ Channel

The following problem was studied: construct arrays with symbols from the alphabet $[q] = \{1, 2, ..., q\}$ so that in every set of $L$ rows, there is a column where all $q$ symbols appear. Ideally one would like to construct such arrays with $n$ columns and $m = q^{\rho n}$ rows for $\rho \in [0,1]$ as large as possible. The best possible $\rho$ depends on the parameter $L$ (called list size). It is known that $\rho$ must fall at least as fast $1/q$ if $L$ is not allowed to grow with $n$ (but it may depend on $q$); a result of Fredman and Komlós showed that if $L = q$, then $\rho$ must fall exponentially as $q$ increases. It was conjectured that for $\rho$ to grow only moderately (as the reciprocal of a polynomial in $q$ say), then $L$ must be allowed to grow as $q \ln q$. A precise form of this conjecture was established. [S. Bhandari and J. Radhakrishnan]

Zeros of Polynomials, Algorithms and Combinatorics

A new deterministic polynomial polynomial time algorithm for approximating the partition function of the ferromagnetic Ising model at constant non-zero fields, derived by exploiting a recent algorithmic version of the classical Lee-Yang theory of phase transitions proposed by Alexander Barvinok, was given. New Lee-Yang theorems extending classical work of Suzuki and Fischer were also derived in this work. [P. Srivastava, J. Liu and A. Sinclair (University of California, Berkeley)]

In another work in this area, “correlation decay” based techniques inspired from statistical mechanics were generalized to approximate the partition function of the hard core lattice gas model even when the parameters of the model are complex numbers (and thus, there is no underlying probability distribution and, a priori no “correlation” to speak of). An optimal upper bound on the running time of the resulting algorithm was also established, and as a consequence new applications to algorithmic versions of the Lovász local lemma were found. [P. Srivastava, N. J. A. Harvey (University of British Columbia, Canada) and J. Vondrák (Stanford University, USA)]

Applied Probability

Designing the Perfect Exam

We consider the problem of optimally setting the level of difficulty of questions in an exam paper for a number of reasonable objective functions. This is addressed in two settings: 1) Questions are set at one go and a large number of students need to solve them as in JEE, 2) Questions are sequentially asked and their difficulty level is adaptively adjusted, as in online exams. Key assumption is that probability of correctly answering any question is a decreasing function of its hardness and an increasing function of student’s ability. The latter is modelled as a realization from a probability distribution. [S. K. Juneja, A. Bassamboo (Northwestern University, USA) and A. Zeevi (Columbia University, USA)]

Determining the Equilibrium Customer Arrival Profile to a Transient Queue for Nonlinear Customer Costs

We consider a queuing setting where customers belong to finitely many classes and are modelled as fluid particles. Their cost functions correspond to a linear function of the waiting times and a non-linear function of the preferred time to service. In this framework we identify the unique equilibrium customer arrival profile. We also develop algorithms to quickly identify this profile. [S. K. Juneja, N. Shimkin (Technion, Israel)]

Electrical Networks

Electrical networks are useful in providing a language for many graph algorithms. Examples of such algorithms include work on Max-Flow and Graph Sparsification.
Manifold Learning

In recent years, high dimensional statistics has focused on methods of alleviating the curse of dimensionality. One assumption that facilitates this is the Manifold hypothesis: that data lie in the vicinity of a low dimensional manifold. This could be due to the generating process possessing symmetries and/or few essential degrees of freedom. Manifold learning is a collection of methodologies for analyzing high dimensional data based on the Manifold hypothesis. This has been an area of intense activity over the past two decades. A central question is estimating a manifold from containing a set of points, where the manifold has an upper bound on its curvatures.

Randomized Interior Point Methods

One area of research that I have been involved in for the past decade is that of “Randomized Interior point methods”. The idea here is to put together techniques from interior point methods for convex optimization and methods of analysis of Markov chains to develop new and faster algorithms for sampling convex sets.

Sample Complexity of Partition Identification through Exploration Using Multi Armed Bandit Methodology

Traditionally, multi armed bandit problem corresponds to independently sequentially sampling from multiple arms or distributions, and identifying the best one in terms of the associated mean. Under pure exploration, the objective is to find the best arm with large probability using a minimal number of arm pulls. Generalizations such as finding the top k arms have also recently been studied, where lower bounds and matching upper bounds on computational effort have been developed. We study a substantially generalized framework where the distribution of arms is identified by a vector of parameters, and we need to identify through sequential sampling one amongst many partitions of the parametric space that given set of arms belong to. We develop lower bounds and matching upper bounds on computational effort in this setting, pointing out interesting asymmetries in computational effort as a function of the partition. [S. K. Juneja and S. Krishnasamy]

Structure Recovery in Block Models

Phase transitions in the mean field Ising model were shown to dictate the sample complexity of recovering latent structures in models of social networks. [P. Srivastava, Q. Berthet (University of Cambridge, UK) and P. Rigollet (Massachusetts Institute of Technology, USA)]

Information Theory and Cryptography

Coordination Using Individually Shared Randomness

Two processors output correlated sequences using the help of a coordinator with whom they individually share independent randomness. For the case of unlimited shared randomness, we characterize the rate of communication required from the coordinator to the processors over a broadcast link. We also give an achievable trade-off between the communication and shared randomness rates. [G. Kurri, V. Prabhakaran and A. Sarwate (Rutgers University, USA)]

Distributed Estimation in the Presence of Adversaries

We studied a distributed estimation problem (also known as remote source coding) where parties make noisy observations of a source whose estimate is desired at one of the parties (fusion center). We considered a two-sensor model where an adversary has some control over the noisy observations made. Specifically, the source data is broadcast over an arbitrarily varying channel (AVC) controlled by an adversary. One output of the AVC is received as input at the encoder, and another output is received as side information at the decoder. The adversary is assumed to know the source data non-causally, and can employ randomized jamming strategies arbitrarily correlated to the source data. The decoder reconstructs the source data from the encoded message and the side information. We prove upper and lower bounds on the adversarial rate distortion function for the source under randomized coding. Furthermore, we present some interesting special cases of our general setup where the above bounds coincide, and thus, provide their complete rate distortion function characterization. [A. Budkuley]
Plausible Deniability

We introduced the notion of plausible deniability in an information theoretic framework. We considered a scenario where an entity that eavesdrops through a broadcast channel summons one of the parties in a communication protocol to reveal their message (or signal vector). It is desirable that the summoned party have enough freedom to produce a fake output that is likely plausible given the eavesdropper’s observation. We examined three variants of this problem — Message Deniability, Transmitter Deniability, and Receiver Deniability. In the first setting, the message sender is summoned to produce the sent message. Similarly, in the second and third settings, the transmitter and the receiver are required to produce the transmitted codeword, and the received vector respectively. For each of these settings, we examined the maximum communication rate that allows a given minimum rate of plausible fake outputs. For the Message Deniability problem, we fully characterised the capacity region for general broadcast channels, while for the Transmitter and Receiver Deniability problem, we gave an achievable rate region. [M. Bakshi (Chinese University of Hong Kong, Hong Kong) and V. Prabhakaran]

Private Index Coding

We study the problem of index coding under the privacy requirement that receivers do not learn anything more than the messages they already have as side information and the message they want from the server. To achieve this private index coding, we consider the use of secret keys that are shared among various subsets of users and the server. We characterize key access structures that allow private index coding. For up to three receivers, we characterize the rate region of transmission and key rates and show that scalar coding is optimal; we also show that scalar linear codes are sub-optimal for four receivers. Furthermore, when no keys are available, we consider a weaker notion of privacy analogous to weak security. Finally, for a different setting in which the server is allowed to send messages exclusively to a subset of users, we study the number of transmissions required to achieve error-free decoding and privacy. [V. Narayanan, V. Prabhakaran, J. Ravi, V. Mishra, B. Dey and N. Karamchandani (Indian Institute of Technology, Mumbai)]

Secure Multiparty Computation

The goal of secure multiparty computation is to carry out computations on inputs distributed among two or more parties, so as to provide each of them with no more information than what the respective inputs and outputs reveal to each party. This models several practical settings where mutually distrusting parties need to collaborate, e.g., private auctions, privacy-preserving data mining, electronic voting, to name a few. The aim of this ongoing project is to derive optimal protocols for secure multiparty computations. We studied information theoretically secure computation over a graphical network and characterised topologies which allow secure computation. In a separate work we studied the role of interaction and common randomness in two-party secure computation. [V. Narayanan, V. Prabhakaran, G. Kurri and J. Ravi]

Logic in Computer Science

Formal Correctness of Virtual Memory Management

Modern operating systems for mobile devices are designed to perform in a way which requires minimization of the amount of kernel code that operates in the privileged mode. Various such operating systems have been developed and deployed in recent years. We have designed mechanisms for formal specifications of services and policies of such operating systems by using a two-level approach — where the initial level formalizes all the services that are provided by the kernel, and the next level deals with properties such as non-interference from other modules. These specifications have been used for developing proofs of formal correctness of implementations of virtual memory management units. [N. Raja]

Square of Oppositions and Automated Proof-Checking

An interesting instantiation of Aristotle’s traditional square of opposition is provided at the meta-level by the oppositions between pure and applied logics. In the
specific context of the area of formal logic, Aristotle’s square may be viewed as an attempt to deconstruct the traditional opposition between proof theory and model theory. We have used the framework of the square to unify the oppositions between proof theory and model theory using instances from the field of automated proof-checking. [N. Raja]

**Team Semantics and Axiomatization of Modal Logics**

The area of team semantics has evolved from extensions of classical tarskian semantics for first-order logic. Team semantics provides the appropriate concepts and tools to study axiomatizations of various modal logics. While tarskian semantics uses the notion of a single assignment which satisfies a formula, the notion of team semantics requires a set of multiple assignments which satisfy a formula. Such teams of multiple satisfying assignments help in elucidating the axiomatizability of validity in specialized classes of logics. We have shown how the notion of team semantics can be meaningfully generalized to cover modal operators in variants of modal logics containing second-order predicates. [N. Raja]

**Quantum Information Theory**

**Estimating Average Gate Fidelity Using Few Random Bits**

The average fidelity of a quantum circuit gate is the Haar average, over all input states to the gate, of the fidelity between the ideal output of the gate vis a vis the actual output. It is a measure of the quality of the gate i.e. high average fidelity means the actual physical gate performs almost as well as its mathematical ideal. Estimating average gate fidelity is an important task in benchmarking the quality of experimental realisations of quantum circuits. Previous algorithms for estimating fidelity to within $\varepsilon$ for a $d$-dimensional gate used at least $O(\varepsilon^{-2} (\log d) \log(1/\varepsilon))$ random bits, using efficient approximate unitary 2-designs. We give, using an efficient approximate unitary 4-design and choosing pairwise independent samples from the design via 2-universal hashing, an efficient algorithm for estimating average gate fidelity using only $O((\log d) \log(1/\varepsilon))$ random bits. [A. Nema and P. Sen]

**Verification of Concurrent Programs**

**Synthesis of Vesicle Terrific Systems**

We have developed a tool for synthesis of vesicle terrific system. We have also worked for developing a complete proof method for C11 weak memory model. We have improved TILER, a tool for verification of array related programs, for handling wide range of properties. [A. Gupta]

**Wireless Ad Hoc and Sensor Networks**

**Cellular Wireless Networks**

Earlier definitions of capacity for wireless networks, e.g., transport or transmission capacity, for which exact theoretical results are known, are well suited for ad hoc networks but are not directly applicable for cellular wireless networks, where large-scale basestation (BS) coordination is not possible, and retransmissions/ARQ under the SINR model is a universal feature. In this work, we consider cellular wireless networks, where both BS locations and mobile user (MU) locations are distributed as independent Poisson point, and each MU connects to its nearest BS. With ARQ, under the SINR model, the effective downlink rate of packet transmission is the reciprocal of the expected delay (number of retransmissions needed till success), which we use as our network capacity definition after scaling it with the BS density. The goal is to find an exact characterization of this natural capacity metric for cellular wireless. [R. Vaze]

**Online Algorithms for Basestation Allocation**

Online Algorithms for Resource Allocation Problems. In this area of research we concentrate on three modern non-ergodic paradigms in networking; green communication, device-to-device (D2D) communication (equivalent to crowdsourcing), and combinatorial/strategic resource allocation. The common theme for the algorithm design among the three areas is the uncertainty about future information
about energy arrivals/availability, strategic user behavior, and available resources, respectively. The design tools for deriving online algorithms for these areas have a large intersection and we plan to come up with a common set of design directions for the three listed areas which we believe are at the core of modern communication network design. [R. Vaze]

**Renewable Energy**

Using renewable sources of energy for powering wireless communication systems has been proposed to increase lifetime of sensor networks, improve energy efficiency of low power devices, and also provide a means for green communication. Recent hardware progress has contributed towards realizing efficient practical design of small sized energy harvesting devices with sufficient power yield required for communication purposes. Harvesting energy from natural sources, however, makes the future available energy levels at the transmitters unpredictable and the transmitter has to adaptively choose the transmission power for maximizing its utility function. We are trying to derive an analytical framework for design of renewable energy sources powered wireless communication system. The objectives of the project are as follows:

1. Characterizing the fundamental limits such as capacity, reliability, coverage and connectivity, of wireless networks (e.g. ad hoc, relay assisted, overlaid heterogeneous, sensor etc.) when each node uses energy harvested from renewable energy source.

2. Develop a theoretical framework for the design of renewable energy sources powered wireless communication systems that is free of energy arrival distribution or allows arbitrary energy arrivals. [R. Vaze]

**Information System Development Group**

The Information Systems Development Group (ISDG) of TIFR supports the institute by implementing software solutions required by various administrative processes. All major processes related to Accounts, Finance, Purchase, Stores and Establishment is digitized and their operations automated as part of the in-house developed ERP package TIIS (TIFR's Integrated Information System). Workflows like guesthouse booking, lecture room booking, vehicle requisition etc. are made available under the institute’s intranet named ‘Datanet’. Some of the activities taken up by ISDG from April 2017 to March 2018 are given below. These are in addition to the regular maintenance and enhancements of existing packages as well as the generation of various reports required from time to time by DAE and/or data analysis.

**7th CPC Pay and Pension Implementation**

7th CPC pay was implemented in March 2017 with a payment of 96% of basic initially. After April 2017, full implementation was done along with various other components. Associated changes were made in all salary programs like LTC, TADA, Gratuity, EL Encashment. Pension was revised and disbursed in three phases: Pre 2016 pensioners, Post February 2017 pensioners, January-February 2017 pensioners. Changes were made to segregate standard and voluntary PF for re-computation. Accommodation seniority list was modified with rules and eligibility as per 7th cpc.

**Implementation Efforts at Centres**

In lines with TIFR Mumbai, implementation support of TIFR datanet and its modules comprising Purchase, Stores, Payroll, Establishment were given at TCIS and NCBS. HBCSE and CAM was added in April 2018. Customizations were made to the purchase and stores module to meet the requirements of NCBS. The deployment model is centralized where a common HR database is shared with center wise databases for accounts, purchase and stores.

**Accounting System for Resource Generation Committee**

An entirely new and separate accounting system was developed for Resource Generation Committee. A framework for a separate series of budget account that starts with R was prepared. All accounting systems like Bills receivables, Subsidiary JV, Ledgers and Trial balance were provided here and also integrated with the budgeting system.

**Goods and Service Tax**

With the implementation of Goods and Service Tax in our country, it was important and time bound to
implement necessary changes in TIIS also. Purchase, Stores and Accounts system was modified to include additional fields capturing GST with HAC Code, CGST, SGST and IGST.

Medical Software

Based on the specifications received from Medical section an electronic healthcare system was developed with features for patient history, appointments, prescriptions, pathology appointments, medical inventory etc. The system has been released in April 2018. A system for adding and maintaining radioactive sources and equipments inventory with details of their strength, cost, owners and location was developed.

Human Resource System

The existing module of HR having muster, extensions and enhancements, probations, superannuation, certificates and letters and PRIS was redeveloped in Java.

Leave Module (Other leaves)

The online leave module was extended with all remaining types of leaves. Now all leaves are part of the online system except Deputation leave. The system was also enhanced to handle exceptions where-in the application is accepted even if some validations fail but Establishment can then forward it to a higher authority for final sanctioning.

Cashless Canteen System

A new version of cashless canteen system was released where the cashier and user tablet communication was moved from WiFi to Bluetooth. This removed the dependence on WiFi connectivity for tablets to work in offline mode under all situations. Infrastructure Several infrastructure related changes were undertaken like datanet on https, setting up a version control for release and development separately and automating backups of releases.

Members


Adjunct Professor/Associate Faculty

R. Basu (since 01/09/2017), V.S. Borkar (till 31/03/2018), D. Shah (since 01/03/2018)

Scientific Officers

N. Bondale, N. S. Gawandi and R. J. Naik

Information Systems Development Group


Technical Staff

P. N. Bhuwad

Research Scholars


Visiting Fellows

V. Chintala (from April till July 2017), P. Dey (till March 2018), S. Krishnasamy (from September 2017), R. M. Matteplackel, S. B. Moka (till August 2017), J. Ravi (from July to December 2017), S. Tirodkar, M. Vinyals (from
September 2017)

Junior Research Fellows
S. Agrawal (till July 2017), A. V. Deshpande (till September 2017)

Office Staff
J. Barretto (till November 2017), P. Supriya (since May 2017)

Work Assistant
W. K. Gawade

National and International Involvement

U. Bhaskar
1. Member, Program Committee, ACM EC 2017, 2018
2. Member, Program Committee, WINE 2018

N. Bondale
Member, Organizing Committee, Fifth International Conference- Science and Scientist, 2017

P. Harsha
1. Associate Editor, SIAM Journal on Computing, 2017–present
2. Guest Editor, CCC 2016 Special Issue in Theory of Computing (ToC) journal

S. K. Juneja
1. Associate Editor, Stochastic Systems
2. Member, National Advisory Board, Economic Sciences, Indian Institute of Technology, Kanpur
3. Member, Academic Council, Indira Gandhi Institute for Developmental Research, Mumbai
4. Member, Program Committee, INFORMS Applied Probability Conference, Northwestern University, USA

T. Kavitha
1. Member, Program Committee, 19th ACM Conference on Economics and Computation (EC), 2018
2. Associate Editor, ACM Transactions on Algorithms

H. Narayanan
STOC’17, SIAM Journal of Computing and Annals of Statistics

V. Prabhakaran
Associate Editor, IEEE Transactions on Information Theory

N. Raja
2. Member, Advisory Board, Cauvery Research Journal, Bharathidasan University, 2017–18
3. Member, Advisory Committee, Fourteenth International Conference on Distributed Computing and Internet Technologies, India, 2018
4. Jury Member, Bimal Krishna Matilal Logic Prize for India, CLC, Vichy, France (2018)
5. Member, Editorial Board:
   (iii) ISTE International Journal of Computer Science and Engineering, ISTE Publications, 2017–18
6. Member, Program Committee:
   (i) Second International Conference on Accessibility to Digital World, (ICADW), Tezpur, 2017
   (ii) Non-Classical Logics, Special Track of the 30th International Conference of the Florida Artificial Intelligence Research Society, Florida, U.S.A., 2017
   (iii) Twelfth International Conference on Risks and Security of Internet and Systems, Dinard, Brittany, France, 2017
   (iv) Seventeenth International Conference on Innovations for Community Services, Darmstadt, Germany, 2017
   (v) Third Symposium on Dependable Software Engineering, Changsha, China, 2017

P. Srivastava
Member, PhD Thesis Committee, Damian Straszak École Polytechnique Fédérale de Lausanne, Switzerland), December 2017

R. Vaze
2. TPC Member, WiOpt 2018, SPCOM 2018, NCC 2018
Visits

U. Bhaskar
Workshop on “Dynamic Traffic Models in Transportation Science”, Dagstuhl, Germany, March 04–09, 2018

P. Harsha
Department of Applied Mathematics and Computer Science, Weizmann Institute of Science, Israel, February 24 – July 31, 2017 (on sabbatical leave)

S. K. Jungra
1. IIT, Gandhinagar, May 15–16, 2017
2. INFORMS Applied Probability Conference, Northwestern University, USA, July 06–13, 2017
3. IFIP Performance 2017 Conference, Columbia University, USA, November 12–17, 2017
4. LPS XII, Indian Statistical Institute, Kolkata, December 15–19, 2017
5. Indian Statistical Institute, New Delhi, Jan 9–11, 2018

T. Karitha
Max–Planck Institut für Informatik, Saarbrücken, Germany, May 08–29, 2017

H. Narayanan
1. University College London, UK, April 2017
2. Princeton University, USA, September 2017
3. Indian Statistical Institute, Kolkata, December 2017

Invited Talks

U. Bhaskar
Using Tolls and Signals to Obtain Good Equilibria in Routing Games. IEOR department meeting, Indian Institute of Technology, Mumbai, February 26, 2018

A. Chattopadhyay
1. Weights at the Bottom Matter When the Top is Heavy. Algorithms and Complexity Seminar, Oxford University, United Kingdom, October 2017

P. Harsha
Expanders: Ramanujan graphs and their applications. 3 lecture course at SERB School on Nonlinear Dynamics, Department of Mathematics, Savitribai Phule Pune University, January 27–29, 2018

S. K. Jungra
4. Rest in the Lounge or Directly Join the Queue. 19th INFORMS Applied Probability Society Conference, Northwestern University, USA, July 10–12, 2017
5. Selection of the Best System Using Large Deviations, and Multi-Arm Bandits. A Program on Large Deviation Theory in Statistical Physics: Recent Advances and Future Challenges, ICTS, Bangalore, August 23, 2017
6. Credit Risk: Simple Closed Form Approximate Maximum Likelihood Estimator, Comparison and Analysis. IGIDR-NESI, Workshop on Mathematics and Economics, September 02, 2017
7. Portfolio Credit Risk: Simple Closed Form Approximate Maximum Likelihood Estimator and Related Issues. Colloquium, ICTS, Bangalore, September 04, 2017
10. Financial Credit Risk. Seminar organized by Mechanical Engineering Society, IIT, New Delhi, January 10, 2018
11. Queueing Games: To Wait or To Be Late. Colloquium, CEBS, Mumbai, January 18, 2018

T. Kartha
1. Popularity, Mixed Matchings, and Self-Duality. Max-Planck Institut für Informatik, Saarbrücken, Germany, May 11, 2017
4. Popular Matchings with Multiple Partners. FSTTCS 2017, IIT, Kanpur, December 13, 2017


H. Narayanan
1. Randomized Interior Point Methods. LPS XII, Indian Statistical Institute, Kolkata, December 18, 2017
2. Fitting Manifolds to Noisy Data. Statistical Physics Methods in Machine Learning, ICTS, Bangalore, December 30, 2017

J. Radhakrishnan
1. Better Bounds for Perfect Hashing Into a Four Element Set. From Information Theory to Combinatorics, Workshop in honour of János Körner, Sapienza University, Rome, Italy, November 10, 2017
2. Communication Assisted Agreement Distillation. University of Brescia, Italy, November 16, 2017

Conferences / Workshops Organized by the School

Workshop on “Bombay Information Theory Seminar (BITS 2018)”
Jointly by IIT Mumbai and TIFR, January 11–14, 2018 (Organisers: V. M. Prabhakaran and J. Radhakrishnan)

Non-DAE Research Projects

U. Bhaskar

H. Narayanan
1. Fitting Manifolds to Noisy Data, NSF 1620102, September 2016–August 2019
2. Ramanujan Fellowship, DST-SERB, August 2016–May 2021

V. Prabhakaran
Indo-Israel Joint Research Cooperation Programme, 2018–2020 (with S. Agrawal, Y. Ishai, E. Kushilevitz, A. Rosen)

N. Raja
Principal Investigator, Centre for Formal Development and Verification of Software (CFDVS), IIT, Mumbai, 2017–18

R. Saptharishi
Ramanujan Fellowship, DST-SERB, August 2017–May 2022

P. Srivastava
Ramanujan Fellowship, SERB-DST, New Delhi, Feb 2018

R. Vaze
1. Indian National Science Academy’s Young Scientist Award Grant: Design of Efficient Spatial Wireless Networks Using Stochastic Geometric Tools, June 2014–May 2018 (15 Lakhs for 3 years)
2. CEFIPRA Indo-French joint program on D2D Communications for LTE-Advanced Cellular Networks, April 2015–April 2018 (Rs. 10.00 Lakhs for 3 years)
Along with the routine work following were the activities carried out by the accounts section during the year 2017–18

- Statutory Audit for the F.Y.2016-17 was completed and Draft Audit report was ready by the last week of July.2017 All the staff members cooperated very well by completing their assigned job within stipulated time. All are deserving a very big appreciation for completing the Balance Sheet work in such a record time. Total three qualification was noted by the Auditors out of which two were pertains to NCBS and regarding Mumbai a qualification was recorded for non-active project accounts.

- During the financial year 413 foreign deputation claims were settled and 310 advances were given. Total 112 vouchers of travel Agent were booked. Total expenditure amounting to Rs.519 lac were incurred under foreign travel. Around 1015 local claims were settled and 320 advance was given. Total 39 travel Agent voucher was booked total expenditure against local travel was Rs. 216 lac.

- More than 2000 cases settled towards travelling allowance for students, RS, VSRP, and VF etc. who came for Interview. LTC claim settled for 495 cases and advances given to 257 cases totaling to 153 Lac. Mrs. Rekha Raikar in charge of this section effectively handled the work along with Mr. Manoj Singh, and Ms. Pranali Gujare.

- Total 3557 files were pre-audited and budgeted during the year 2017–18. Mr. Raju Verma, this year closed more than 20 projects with proper procedure out of the total 162 projects. Mr. Bhujbal helped with pre-auditing the files and Mr. Zadpe looks after the DAE related business. Mr. Zadpe manages the Budget and Pre-audit Group effectively. This year new activity of resources generation is started and a TT and RGC group was created. All the accounting work, creation of the database and the creations of accounting procedures with the help of ISDG was done by Mr. Zadpe. At present there are 5 projects having a total amount of Rs.1.55 cr. is operative in the system.

- Regarding payment to suppliers and related activity like TDS, Form 16 etc. were paid on time and Form 16 was generated online and given to suppliers and flat owners. Over 8500 local bills which include supplier’s bill, Bills through MB recording, electricity bills and telephone bills were passed and paid by Mr. Prakash Dandekar, Ms. Manisha Rele and Mrs. Vrushali Sawant.

- On the foreign payment desk cashier disbursed around 3.5 cr. Cash during the year with an average of 1.5 lac as daily withdrawal from the bank. Total 89 LC’s were opened along with 139 files for advance payment, 105 files for local payment through A2 forms and 340 files for bill of entry payment were made during the year 2017–2018 Custom duty paid for 1.68 cr and CCR paid for 12 lac along with Insurance charges above Rs. 9 lac. During the same year. Mr. Nitin Hanjankar were taken effort to execute the work. Cash was handled by Mr. Vedant Nakha. In financial year 2017-18 around 12,000 debit vouchers and 1748 credit vouchers were booked in the cash book (Both CBI and SBI) which was maintained by Mr. Anoop Salgaonkar.

- Salary department has done a splendid job in the year 2016–17. Total 51 cases of Superannuation were settled along with 204 cases of fixed salary staff, RS, VF who resigned from the Institute. The Retrospective effect of DA enhancement, twice in a year was given immediately to the retired staff members along with salary arrears, Gratuity arrears and E.L. encashment arrears. Mr. Sanjay Bhosale has effectively handled the work of the Pension with the help and guidance from Mr. Prajith Kumar.

- The Last year balance work of implementation of Salary as per 7 CPC was completed by the Salary Section.

Filing of income tax returns within the prescribed time, issuing of From 16 to staff members (approx. 2500 no.) of the Institute, was done efficiently by
the staff members of the Salary section under the guidance of Mr. Prajith Kumar. Most of the data feeding work like, HRA allowance, Transport Charges, recovery, Recreation and Sports club recovery, Festival Advance, Medical allowance, night duty allowance, tuition fees, overtime calculation and feeding etc. done by Mr. Abhishek Hirlekar and Mr. Rahul Nimbkar very efficiently.

- Along with the income tax, e-filing of return for Professional Tax was also done within the given time.
- PF/HBA department handled by Mr. Khan and Ms. Deepali Raut. The PF Balance sheet was prepared and completed within one month in the year 2017–18. 25 refundable and 186 non-refundable loans were distributed during the year, amounting to Rs.43.90 Lac and Rs.495.89 lac respectively. Final settlement was made towards 51 retirement cases. Mr. Khan also uploaded NPS data to NSDL and remit the funds to the designated NPS bank every month within the stipulated time.
- This year, auditors from CAG as well as from IIW DAE conducted their audit of The Institute. Both have completed the audit for FY 2016–17. This year CAG conducted he audit for NCBS and NCRA and raised the qualification in a single report. All the paras raised were replied immediately. At present some paras of CAG audit and IIW DAE audit were pending.
- All the senior Accounts Officer has taken the exhaustive efforts hence section was able to make the newest achievements during the year 2017–18.

[Kishor Paithankar (Head Accounts)]

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**Canteen**

The Canteen Department functions for 365 days in a year in multiple shifts and is also operational on Saturdays, Sundays and Holidays apart from the weekdays. The department caters to around 2400 to 2500 people daily providing services like the Breakfast, Lunch, Evening Tea and Dinner. The department also caters to NSF Colloquia on Wednesdays, Math’s Colloquium on Thursdays, Aset Colloquia on Fridays and Special Colloquia as and when organized.

The department also caters to the Room Service requirement of the Institute providing Tea/Coffee/Biscuits as per the Room Service orders placed with the department. The Canteen Services are time bound and the department has always provided all its services on time. Apart from the regular Canteen services the department also caters to Food and Beverage requirements of various Seminars, Workshops, and Public Lectures etc organized in the Institute. These arrangements are made without affecting the normal canteen services and other day to day requirements of the faculties.

The Cashless System was introduced in the Canteen Section with QR codes since 1 April 2014 which is a big progressive step in the operations of the Canteen has helped in fast movement of the queue, proper accountability for both users as well as Canteen section, and is very user friendly.

The Canteen Department consists of the A.O, Supervisors, Cash Clerks, Cooks, Cook Mates, Seullery Boys and Bearers and it is a team effort of all the staff members in providing efficient and timely services of the department. [A. V. Tambe, In-Charge Canteen]

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**Computer Centre and Communication Facility (CCCF)**

*Installation and Commissioning*

1. Redundant Data Centre (RDC) was commissioned at WS03 for ensuring uninterrupted internet connectivity and mail spooling in the event of a planned shutdown at main data centre. [Sri. Vijay Naik, Sri. H. Raghavan and CCCF team]

2. Computer Centre (CC) commissioned FTTH [Fiber To The Home] Internet connectivity to Colaba Colony residences. Fiber backbone was commissioned and connectivity was provided to each flat for data, voice and image communication. Redundant up-links to colony network is commissioned for reliable connectivity. Two stacks
of network switches in High Availability (HA) mode for maximum network uptime is designed and rolled out. Security is enforced at firewall to ensure colony network traffic isolation from institute network. [Sri. Vijay Naik, Sri. H. Raghavan and CCCF team]

3. Centrally managed wireless network is implemented for the STCS, School of Mathematics and DTP departments to eliminate small wireless network silos and bring the departments entirely under the TIFR WIFI network. [Vinit Bhosle, Vinod Lad, Swapnil Malvankar]

4. Emergency services at RDC: Redundant internet links from service providers M/s Reliance Communication and M/s NKN commissioned at RDC for resilient internet connectivity and maximum uptime. [Shisheer Teli, Rahul Auchare] Redundant name server, mail exchanger, servers & storage setup commissioned at RDC for internet and mail pooling [Santosh Kyadari, Sagar Mungse].

Upgrade and maintenance

1. SSL-VPN server has been upgraded for better security and improved performance [Vinit Bhosle]

2. Mathematica, Sigmaplot, Autodesk, Intel C++/Fortran, LabVIEW, MathWorks, Origin Lab and SolidWorks scientific software upgraded to the latest version. Scientific application software SNEC and MolPro implemented on IBM HPC cluster. HPC software stack is upgraded to the highest level for better HPC performance and security [Anilkumar J. Naik]


4. Domain Message Authentication Reporting and Conformance (DMARC), Domain Key Identified Mail (DKIM) and Sender Policy Framework (SPF) security features implemented at the mail server to check the authenticity of sent and received mails. DMARC checks both sender and recipient domain SPF, DKIM mechanisms and decides the fate of the mails based on the sender domain policy, whether to reject the mail or to accept the mail. [Sagar Mungse, Santosh Kyadari]

5. Replacement of Distribution Layer switches: Obsolete network switches were replaced by new 10/100/1000 Mbps switches in the complete institute. New switches are configured in virtual chassis mode for easy O&M (Operations and Management) [Shisheer Teli, Rahul Auchare, Vijay M Naik, Narayan Karle, Kiran Shirodkar, Vinod Lad, Swapnil Malvankar]

Application Development and Automation

1. Automatic e-mail notice generation from Indico application for new NSF (Natural Science Faculty) events to registered users and event reminder was developed and deployed to stop manual process. [Anilkumar J. Naik]

2. A guest registration portal is developed and implemented for academic guests to the institute for enrolling to the institute wireless network. Guests can self-register and get connected to the TIFR-GUEST wireless network automatically after necessary checks. [Vinit Bhosle, Shisheer Teli, Siraj Momin, Kausalya Srinivas]

3. Wireless network segmentation for SSID named TIFR-WIFI is implemented for all the departments to access control to restrict access to their department resources. [Vinit Bhosle, Shisheer Teli, Rahul Auchare, Siraj Momin]

4. Developed and deployed web based printing application to manage network printing to CC printers. This web based application printing with accounting and quota from desktop and mobile users has helped to reduce excess printing from users. [Anilkumar J. Naik, Kausalya Srinivas].

5. Online visitor request & approval system developed and implemented for academic use. [Sayali Goregaonkar, Kausalya Srinivas]

6. Subject Board of Physics (SBP) registration tool for students was developed and deployed [Siraj Momin, Kausalya Srinivas]

7. Network traffic monitoring: NBOX and DCNTOPNG for deep network traffic monitoring; Implemented NTOPNG PRO for network traffic monitoring. Network traffic related information like bandwidth utilization, top application in use, Per IP historical traffic information, and L2 + L3 switch traffic, SNMP device management, alerts of network issues and historical reporting is available for analysis.
Implemented JSON flow monitoring from ntopng traffic alerts using web and mobile application SLACK. [Anilkumar J. Naik]

**Training and Workshop**

1. Participated on behalf of TIFR in National Symposium on NSM Grid over NKN conducted by CDAC & NKN in Bangalore. [Kausalya Srinivas]


**Members**


**Trainee Engineer**

Sayali Goregaonkar

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**Cosmetic Maintenance**

The cleanliness and elegant look of TIFR premises is the responsibility of the Section, which works on all 365 days in different shifts. The major tasks of the section includes cleanliness of entire premises in all respect, pest control services, carpet cleaning works with outside contractors, procuring new carpets, coir mats as and when requires, taking care of upholstery work, providing new curtains, arranging curtains for washing, handling the laundry works etc. Special care was taken during the year for VVIP’s visits, Seminars, Conference and Lectures. Special care was also taken during Council meeting of the Institute in time to time. [P.S. Palav; Staff Strength: 44]

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**Medical section**

Total number of patients: 13801; Dressing: 793; Injections: 292; ECG: 226; Eye irrigation: 82; Strapping: 94; Foreign body removal [from wound/eye, etc.]: 51; Nebulization/Oxygen: 34; US Diathermy: 66; Short wave diathermy: 96; On duty injury: 38; New appointments [category B, C & D]: 196; Diet counseling: 240

**Pathology**

Total tests: 14437; Total patients: 2243; CHSS [Family members]: 292; Annual medical examination: 830

**Health Promotion Centre**

Total number of patients: 1219; Dressing: 62; Injection: 45; ECG: 15; Vaccination: 17; Nebulization: 52; Periscope: 114; Neuroscan: 27; Physiotherapy patients: 260; Physiotherapy sittings: 5371; Psychology counseling: 80 [Employees: 20, Family members: 34, Students: 26]; Ayurveda consultation: 133 [Employees: 70, Family members: 63]

**Other Activities**

1. Diabetes awareness drive on World Diabetes Day, November 14, 2017
2. Automated electrical defibrillator training sessions for Security staff as well as other staff conducted from 8.12.217 to 30.01.2018.
3. Bone mineral density detection camp was
conducted on 08.09.2017. About 140 members participated.

4. To commemorate world health day, a ‘Bharud’ was presented on Depression on 19.04.2017. The same program was conducted in HBCSE on July 1, 2017.

Public Relations and Travel

Public Relations Office is a good source of information about TIFR. This section arranges Public Lectures, helps the conference organizers in getting the approvals from DAE, MEA and MHA, uploading web content related to awards and honours of the staff. The section takes care of visits by Parliament Delegation, Review members, important Government Officials, Defense attaches, Foreign Delegates to TIFR and visits by college students.

This section handles questions by Parliament, Public Grievances appearing in media and also helps in press and media publicity of the institute. The section also looks after Endowment Fund of the institute which operates 27 accounts for different awards and 3 chair professorships.

This section takes care of all the formalities related domestic and international travel including air tickets, visas, foreign exchange, and overseas medical insurance. It also handles short-term & long-term visits of foreign nationals to TIFR and its centres.

This section is also taking care of booking of the Homi Bhabha Auditorium and renewing of its license. Public Relations also takes care of Art and Archives of TIFR.

[R.P. Ambekar (Public Relations Officer); Staff Strength: 3]

Scientific Information Resource Centre

SIRC subscribed to 436 journals of which 220 journals are online only and majority of the remaining journals are Print or Print+Online. SIRC also subscribed 17 e-journals packages to access 3747+ journals. Besides, SIRC has access to 7 new electronic journals under various packages and changed 2 titles from Print + Online to Online Only. A total of 1062 bound volumes and 44 journal CDs were added.

SIRC added to its collection 270 printed books, of which 251 were purchased and 16 were received as ‘gratis’. In addition to this, 41 books were procured for various groups/individuals.

Subscription to e-books published by Springer, European Mathematical Society (EMS) and Society for Industrial and Applied Mathematics (SIAM) was continued. Also SIRC subscribed to Annual Reviews Package, AIP Conference Proceedings and Elsevier e-books Series. In addition to this, 2 AMS e-book series back files recently acquired by TIFR-CAM, Bangaluru are accessible.

Online access to some of the e-resources subscribed by SIRC was continued to all the Centres / Field Stations. Few online packages and online journals were subscribed for TCIS, Hyderabad.

At the Circulation desks (both Books & Journals), approx. 4751 transactions took place. As a part of ILL arrangement, SIRC loaned 18 books to various libraries and requested 2 books on ILL from other libraries. Similarly, SIRC sent out 117 articles and received 41 articles from others. About 3330 pages of photocopies were provided to Institute members. RFID based issue/return system for book collection was inaugurated by Prof. S. Trivedi, Director, TIFR on 30th October 2017, on the occasion of Founder’s Day.

Conferences and Workshops Attended

1. Swapna Kudapkar and Gaurang Dhamdhere, attended National Workshop on ‘Metadata Standards: Retrospective Conversion, Preservation and Migration”, INFLIBNET Centre, Gandhinagar, 7–9 June 2017
2. R. Prabakaran participated in “Librarian’s Appreciation Day” organized by Royal Society of Chemistry (RSC), Jaipur, 28 July 2017
3. R. Prabakaran and D. B. Ghoderao attended the Springer Nature eBook Summit, Kochi, 7–9 Sep 2017
6. R. Prabakaran participated as invited member of “IOP Publishing Library Advisory Board (LAB)” meeting, Goa, 8–9 November 2017
7. R. Prabakaran attended the “Wiley Library Awards 2017”, Delhi, 20 December 2017

Members

Trainees
Poorva M. Hendre (till 8/08/2017), Eureka S. Haldankar (till 4/09/2017)

Central Photocopying Facility

The facility caters to the photocopying needs of the Institute. It also provides multiple copying facility through GESTETNER machine for the conference papers, brochures and various forms required by the departments of the Institute. No. of Photocopies provided: approx. 33373 pages. No. of Multiple copies provided: approx. 60836 pages. [E. A. More]
Publications,
Lectures,
Training
In Journals

15. Indranil Biswas; Giovanni Bazzoni; Marisa Fernández; Vicente Munoz and Aleksy Tralle, Homotopic properties of Kähler orbifolds, Special metrics and group actions in geometry, 23–57, Springer INdAM Ser., 23, Springer, Cham, 2017.
28. Indranil Biswas and Sebastian Heller, On the automorphisms of a rank one Deligne-Hitchin moduli


In Proceedings

Mahan Mj

Arvind N. Nair

J. Sengupta

Raja Sridharan

Books / Book Reviews

Mahan Mj
1. A Crash Course on Knots, Topology and Condensed Matter Physics, TRIPS series, 2017
2. Topology and Condensed Matter Physics, TRIPS series, 2017 (Editor)
TIFR Centre for Applicable Mathematics, Bengaluru

In Journals


Web publications


School of Natural Sciences
Department of Astronomy and Astrophysics

In Journals

2. Asymmetry of Line Profiles of Stellar Oscillations...


53. S. A. Levshakov, K.-W. Ng, C. Henkel, B. Mookerjea “[C II], [C III] and CO emission lines as a probe for z variations at low and high redshifts” MNRAS, 471, 2143, (2017)


61. M. N. Vahia and Ganesh Halkare, Astronomy of tribals of central India, Current Science, 113, 1041 – 1049


68. A. Gopakumar is an author in thirty three LSC papers that appeared during 04/2017 to 03/2018. Few Selected papers are:

a) GW170608: Observation of a 19 Solar-mass Binary Black Hole Coalescence (arXiv:1711.05578)

b) GW170814: A Three-Detector Observation of Gravitational Waves from a Binary Black Hole Coalescence (arXiv:1709.09660)

c) GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral (arXiv:1710.05832)


e) GW170104: Observation of a 50-Solar-Mass Binary Black Hole Coalescence at Redshift 0.2 (arXiv:1706.01812)

In Proceedings


Web Publications


In Books


Technical Reports/Internal Reports

In Journals


Web Publications

Krishanu Ray and Manidipa Banerjee, Cryo-electron Microscopy – photographing molecules as they are, Blogsite-DBT, Govt. of India.
In Journals


Department of Condensed Matter Physics and Material Sciences

In Journal


8. In Proceedings


47. Phase-separated magnetic ground state in Mn$_{2.5}$Ga$_{0.5}$Sn$_{0.5}$O$_{3}$, E. T. Dias, K. R. Priolkar, A. K. Nigam, R. Singh, A. Das, and G. Aquilanti, Phys. Rev. B 95 (2017) 144418.


51. Large spontaneous exchange bias in a weak ferromagnet Pb$_{4}$Ni$_{2}$TeO$_{6}$B. Koteswararao, Tanmoy Chakrabarty, Tathamay Basu, Binoy Krishna Hazra, P. V. Srinivasarao, P. L. Paulose, and S. Srinath, Scientific Reports 7, 8300 (2017).

Department of High Energy Physics

In Journals


LIGO Scientific Collaboration (C. S. Unnikrishnan)


21. All-sky search for long-duration gravitational wave transients in the first Advanced LIGO observing run, Class. Quantum Grav. 35, 065009 (2018).


In Proceedings


Department of Nuclear and Atomic Physics

In Journals


12. Self-assembled photonic crystals of monodisperse dendritic fibrous nanosilica for lasing: Role of fiber


45. Giant dipole resonance and shape transitions in hot and rotating 88Mo. AKR Kumar, P Arumugam, N Din Dang and I Mazumdar, Phys. Rev. C 96, (014309) 2017


54. Low-energy proton induced M X-ray production cross sections for 70Yb, 81Tl and 82Pb, Shehla, A. Mandal, Ajay Kumar, M. Roy Chowdhury, Sanjiv Puri and L. C. Tribedi Nuclear Instr and Methods B, 426, 34 (2018)

55. M X-ray production cross-sections in 79Au and 83Bi induced by 50–300 keV Protons; Anuvab Mandal, Shehla, M. Roy Chowdhury, Ajay Kumar, S. Puri and L.C. Tribedi [Euro Phys. J. D 72 (120) 2018

In Proceedings


2. Lasing from a quasi-one-dimensional array of microresonators. Krishna Chandra Joshi, M. Balasubrahmaniyam and Sushil Mujumdar. 11th India-Singapore Joint Physics Symposium, Nanyang Technological University, Singapore, 5-7 March 2018


10. Performance and imaging capabilities of the DEGAS high-resolution gamma-ray detector array for the DESPEC experiment at FAIR M. Doncel, B. Cederwall, Patale, A. Chatterjee, S. Kailas, p446.


17. Two- and three-body dissociation dynamics of H2O2 at the 7th Topical Conference of Indian Society of Atomic and Molecular Physics, IISER and IIT Tirupati, Tirupati, INDIA, 6-8 January, 2018.


In Journals


16. S. Datta, R. Gavai and S. Gupta, Quark number susceptibilities and equation of state at finite chemical potential in staggered QCD with $N_t=8$ Phys. Rev. D 95 (2017) 054512.


Valeri M. Vinokur, Scaling universality at the dynamic vortex Mott transition, Phys. Rev. B 97, 020504(R) (2018) [Rapid Communications].


In Proceedings


Web Publications


17. Tridib Sadhu, Lecture notes on Macroscopic fluctuation theory. Published on the website of “Bangalore school on statistical Physics VIII”, ICTS-TIFR.

Books/Book Reviews


Research Facilities

TIFR Balloon Facility, Hyderabad

In Journals

3. Sripathi, S., S. Banola, K. Emperumal, B. Suneel Kumar and Sandro M. Radicella (2018), The role of storm time electrodynamics in suppressing the equatorial plasma bubble development in the recovery phase of a geomagnetic storm, J. Geophys. Res. Space Physics, 123.

In Proceedings


Low Temperature Facility

In Journals


National Facility for High Field NMR

In Journals


2. Probing the Potential Role of Non-B DNA Structures at Yeast Meiosis-Specific DNA Double-Strand Breaks Rucha Kshirsagar, Krishnendu Khan, Mamata V. Joshi, Ramakrishna V. Hosur, and K. Muniyappa, Biophysical Journal, 112, 056-2074; 2017

3. 1H, 13C and 15N NMR assignments of an unusual Ca2+-binding protein from Entamoeba histolytica in its apo form, Biomol NMR Assign (2017) 11: 63

4. 1H, 13C and 15N NMR assignments of a bacterial immunoglobulin-like domain (group 2) of a protein of a bacterium Paenarthrobacter aurescens TC1, AD Pawar, D Verma, R Raman, Y Sharma, KVR Chary, Biomol NMR Assign 11: 203, (2017)


6. Strategizing for the purification of a multiple Big domain-containing protein in native conformation is worth it, AD Pawar, D Verma, V Sankeshi, R Raman, Y Sharma, Protein expression and purification, 2018

7. Modulating the Phe–Phe dipeptide aggregation landscape via covalent attachment of an azobenzene photoswitch; M Johny, K Vijayaralachmi, A Das, P Roy, A Mishra and J. Dasgupta; Chemical Communications, 53, 9348-9351, (2017)


15. Understanding of the pathways amyloid-beta takes when it goes from a monomeric to a fibrillar state B. Chandra et al., Biophys. J. 113, 805–816 (2017)


Pelletron LINAC Facility

In Journals


5. Upgradation of Search and Secure System at PLF C. Rozario, S. Pal, S.M. Powale, V. Nanal and
R.G. Pillay, INPAC2018, ID376


TIFR Centres

International Centre for Theoretical Sciences, Bengaluru

In Journals


28. Solid-on-solid contact in a sphere-wall collision in a viscous fluid. Sumit Kumar Birwa, G. Rajalakshmi,
29. Nonlinear travelling waves in rotating Hagen–Poiseuille flow, Benoit Pier and Rama Govindarajan, Fluid Dynamics Research, invited paper, Fluid Dynamics Research, 50, 031402, 2018


34. Algebraic disturbances and their consequences in rotating channel flow, Sharath Jose, Vishnu Kuzhimparampil, Benoit Pier and Rama Govindarajan. Physical Review Fluids, 2, 083901, 2017

35. Two initially spherical bubbles rising in quiescent liquid. Manoj Tripathi, AR Premlatha, Kirti Sahu and Rama Govindarajan. Physical Review Fluids, 2, 073601, 2017


43. How Active Mechanics and Regulatory Biochemistry Combine to Form Patterns i


56. First low-frequency Einstein@Home all-sky search for continuous gravitational waves in Advanced LIGO data,


77. Loss of Locality in Gravitational Correlators with a large number of insertions, Sudip Ghosh and Suvrat Raju, Phys.Rev. D96 (2017) no.6, 066033

78. Smooth Causal Patches for AdS Black Holes, Suvrat Raju, Phys. Rev. D 95, 126002


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2. Tracking the propagation of planetary scale cloud zones over Indian Ocean and South Asia with Markov Random Fields, A. Mitra, A. Apte, R. Govindarajan, V. Vasan, S. Vadlamani. Proceedings of the 7-th International Workshop on Climate Informatics, National Center for Atmospheric Research, Boulder Colorado USA 9-12 2017

3. Flow-induced phase separation of active particles is controlled by boundary conditions, Shashi Thutupalli, Delphine Geyer, Rajesh Singh, Ronojoy Adhikari,
Howard Stone, PNAS, 2018

Web publications

1. Lipschitz Embeddings of Random Fields, Riddhipratham Basu, Vladas Sidoravicius and Allan Sly. Probability Theory and Related Fields, first online Jan 2018
12. Quantum information measures for restricted sets of observables, Suvrat Raju, arXiv:1712.09365

In Books

National Centre for Radio Astrophysics, Pune

In Journals


15. Castelletti, G., Supan, L., Petrelli, A., Giacani, E., and Joshi, B. C., VizieR Online Data Catalog: G29.37+0.1 610MHz image (Castelletti+, 2017), yCat, 360, 2017


18. Deo, Deepak Kumar; Kale, Ruta, Simulations of imaging extended sources using the GMRT and the U-GMRT. Implications to observing strategies, Experimental Astronomy, 44, 165, 2017

19. Das, Barnali; Chandra, Poonam; Wade, Gregg A., Discovery of electron cyclotron Maser emission from the magnetic Bp star HD 133880 with the Giant Metrewave Radio Telescope, Monthly Notices Of The Royal Astronomical Society Letter 464, L61, 2018


22. Grainge, K., and 44 coauthors (including Gupta, Y.), Square Kilometre Array: The radio telescope of the XXI century, Astronomy Reports, 61, No. 4, 288, 2017


27. Iqbal, Asif; Kale, Ruta; Majumdar, Subhabrata; Nath, Biman B.; Pandage, Mahadev; Sharma, Prateek; Malik, Manzoor A.; Raychaudhury, Somak, Active Galactic Nucleus Feedback with the Square Kilometre Array and Implications for Cluster Physics and Cosmology, Journal of Astrophysics and Astronomy, 38, 68, 2017


32. Kanekar N., Neeleman M., Prochaska J. X., Ghosh T., The gas and stellar mass of low-redshift damped Lyman-


34. Kanekar N., Ghosh T., Chengalur J. N., Stringent Constraints on Fundamental Constant Evolution Using Conjugate 18 cm Satellite OH Lines, Physical Review Letters, 120, 061302, 2018


38. Kudale S., Chengalur J. N., Phased array observations with infield phasing, Experimental Astronomy, 44, 97, 2017


47. Mohan, A. and Oberei, D., 4D radio data cubes from spectroscopic-snapshot imaging, Solar Physics, 292, 168, 2017


57. Roychowdhury S., Chengalur J. N., Shi Y., Extended Schmidt law holds for faint dwarf irregular galaxies, Astronomy and Astrophysics, 608, A24, 2017


59. Safutdinov, E. R.; Popov, M. V.; Gupta, Y.; Mitra, D.; Kumar, U., Secondary dynamical spectra of pulsars as indicators of inhomogeneities in the interstellar plasma, Astronomy Reports, 61, No. 4, 406,2017


66. Venturi, T. et al., The two-component giant radio halo in the galaxy cluster Abell 2142, Astronomy and Astrophysics, 603, 125, 2017

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1. Botteon, Andrea; Brunetti, Gianfranco; Dallacasa, Daniele; Gastaldello, Fabio; Kale, Ruta, Non-Thermal Phenomena In El Gordo At z=0.87, Early stages of Galaxy Cluster Formation (GCF), 33, 2017
2. Cano, Zach; Kuin, Paul; Chandra, Poonam; Ashall, Chris; Malesani, Daniele; Pastorello, Andrea, Swift and LT UV and optical observations of type IIn superluminous supernova 2017hir, ATel 10784, 2017
4. Chandra, Poonam; Fransson, Claes; Chevalier, Roger A., Swift-XRT observations of Type IIn supernova SN 2017hec, ATel 10936, 2017
5. Chandra, Poonam; Chevalier, Roger A., Swift-XRT observations of Type IIn supernova ASASSN-17kr a.k.a. SN 2017gas, ATel 10705, 2017
9. Krishnakumar, M. A., Joshi, Bhal Chandra, Basu, A., and Manoharan, P. K., ORT observations of the recent glitch in the Crab pulsar, ATel1, 10947, 2017
10. Nayana, A. J.; Chandra, Poonam, GMRT observations of a Type II supernova SN 2017hpi, ATel 11016, 2017
11. Nayana, A. J.; Chandra, Poonam, GMRT radio upper limits on Type IIin supernova SN 2017hcc, ATel 11015, 2017
12. Nayana, A. J.; Chandra, P., GMRT radio detection of a type II supernova SN 2017cew, ATel 10534, 2017

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1. 2017, Matlab-based GUI for Data Analysis of Real-time RFI Filtering System, Dhaigude, Aishwarya; Desai, Ankita
2. 2017, Interface Of Adis16326 Inertial Sensor With Raspberry Pi, Arun, Satheesh
3. 2017, Symptoms of gear box failure and condition monitoring, Abhijnan Dutta
4. 2017, WEB APPLICATION TOOLS FOR RFI DATA, Sudviilu Subhash Kavale
5. 2017, CHARACTERIZATION OF NEW BROADBAND FEEDS FOR GMRT, Sanket Bhor
6. 2017, Recommended Attenuation Setting for GAB system, Prakash Hande
National Centre for Biological Sciences, Bengaluru

In Journals


29. Shee S, Malhotra V, Raghu P. Protein kinase D regulates metabolism and growth by controlling
43. Rahman MMostafizur, Kecia S, Fernandes G, Chattarji S. Activation of the same mGluR5 receptors in the amygdala causes divergent effects on specific versus indiscriminate fear. Elife. 6 (2017)
61. Caiuco JC, Cooper S, Heigwer F, Warchal S, Qi P, Molnar C, Vasilevich AS, Barry JD, Bansal HSingh,


64. Mirza ZA. Description of a new species of Liocheles Suddeval, 1833 (Hormuridae) from India. Zootaxa (2017)


75. S A (2017)


143. Joshi J, Edgecombe GD. Tracking the variability of phenotypic traits on a molecular phylogeny: an example from scolopendrid centipedes in peninsular India. Organisms Diversity & Evolution. 17(2):393–408 (2017)

144. Kondrhythyn I, Robra L, Thirumalai V. Transcriptional Complexity and Distinct Expression Patterns of autosomal genes in Danio rerio. G3 (Bethesda) (2017)


In Proceedings


Web Publications


3. Jain R., and Brockmann A. Time-restricted foraging under natural light/dark condition shifts the molecular

In Books

Books/Book Reviews

TIFR Centre for Interdisciplinary Sciences, Hyderabad

In Journals


In Proceedings


In Books/Book Chapters

In Journals


In Proceedings


Book Chapters


Books


Edited Books


Expository articles


School of Technology and Computer Science

In Journals


In International Proceedings

3. Bhaskar U., Dani V. and Ghosh A., Truthful and Near-


Web Publications


Technical Reports


School of Mathematics

E. Ghate
1. Sums of Fractions and Finiteness of Monodromy. Groupe d’Étude sur les Problèmes Diophantiens IMJ, Paris 6, April 2017
4. Reductions of Galois representations: Act 1.5. IIT Mumbai, September 13, 2017
5. From Galois Theory to Galois Representations. ISI Delhi, December 11, 2017
6. Reductions of Galois Representations and the Monomial Lattice. ISI Delhi, December 13, 2017

Anish Ghosh
1. Dynamics of group actions on homogeneous spaces. Houston, TX, May 2017
2. Arithmetic Dynamics, IIT Delhi, December 2017
3. Ergodic theory. University of Pune, January 2018

Mahan Mj
1. Geometry of surface group representations. ICTS at Ten, ICTS January 2018
2. Hyperbolic geometry and chaos in the complex plane. Institute colloquium, Harish Chandra Research Institute, December 2017
3. Ending laminations and quasiconvexity. Discussion meeting on Surface group representations, ICTS, November 2017
4. Mini-course of three lectures on Hyperbolic groups, Groups, Geometry and Dynamics workshop, ICTS, November 2017
5. Applications of cuts in Kähler groups. Oberwolfach, October 2017
6. 3-manifolds fibering over the circle and surface group actions on the circle. Grenoble, Inst. Fourier, October 2017
7. Motions of limit sets. First BRICS Mathematics conference, Beijing, August 2017
8. Three lectures on Cannon-Thurston Maps in Kleinian Groups and Geometric Group Theory, Laboratory of Algebraic Geometry, HSE Moscow, June 2017
9. Motions of limit sets. TIFR Colloquium, April 2017
10. Hyperbolic Geometry and Chaos in the Complex Plane. IISER Mohali, April 2017
11. Motions of limit sets. IISER Mohali, April 2017
12. Motions of limit sets. ICTS Bangalore Complex Geometry Workshop, March 2017

Dipendra Prasad
p-adic groups, symmetric spaces and their representation theory. Course of 4 lectures, University of Copenhagen, August 2017

A. Sankaranarayanan
1. Exposure to Goldbach Conjecture and Twin Prime Conjecture. Distinguished lecture, Junior Science Club (JSC), University of Hyderabad, India, September 20, 2017
2. A few glimpses of mathematical contributions of Professor K. Ramachandra. Number Theory Seminar, Department of Mathematics, Yonsei University, Seoul, Republic of Korea, March 20, 2018
3. Riemann zeta-function and some conjectures. Mathematics Colloquium Talk, Department of Mathematics, Yonsei University, Seoul, Republic of Korea, March 22, 2018

Raja Sridharan
Five lectures on Symbolic methods, Madhava camp, St. Xavier’s College, Kolkata, October 2017

Sandeep Varma
1. Introduction to (relative) character theory for p-adic groups. School of Mathematics and Statistics, University of Hyderabad, February 19, 2018
2. Dirichlet’s theorem on primes in arithmetic progressions. School of Mathematics & Statistics, University of Hyderabad, February 20, 2018
3. Galois Theory. Two lectures (and two tutorials), Teachers Enrichment Workshop, NCM, TIFR, Mumbai, March 2018

TIFR Centre for Applicable Mathematics, Bengaluru

C. S. Aravinda
1. Ergodic theory of geodesic flows. Series of six 90 minute lectures, Advanced Training in Mathematics workshop, IIT Delhi, 10–17 December, 2017
2. Geodesic conjugacies of surfaces’ in the Eigen functions Seminar at the Department of Mathematics, IISc, Bangalore, 6 April, 2018

Imran Habib Biswas
Stochastic differential equation. A series of four lectures, CIMPA School, IIT, Kanpur

Shyam Sundar Ghoshal
Scalar conservation law via Hamilton-Jacobi equation. Advance Workshop on Hyperbolic Conservation Laws, SRM University, Chennai, 4–7 December, 2017
Aditi P. Choudhari
1. The first discovery of a gravitational wave from a binary black hole system, at IIT Indore, Indore, 14 January 2018
2. The first observation of a gravitational wave from a neutron star binary system, at IIT Indore, Indore, 16 January 2018
3. The first observation of a gravitational wave from a merger of two neutron stars, at IIT Indore, Indore, 18 January 2018

H. M. Antia
Helioseismic Inversions. IISER Kolkata, March 23, 2018

Sudip Bhattacharyya
1. What limits the spin rates of millisecond pulsars: Disk-magnetosphere interaction or gravitational waves? DAA Interaction Meeting, TIFR, Mumbai, Jan 15–16, 2018
2. ASTROSAT and X-ray astronomy in DAA. The first TIFR-BARC interaction meeting on Astronomy, TIFR, Mumbai, 13 January 2018
3. ASTROSAT: The first dedicated Indian astronomy space mission, IIT Indore, Indore, 04 December 2017

A. Gopakumar
1. Introduction to GWs (3 Lectures). 2017 Asian-Pacific Summer School and Workshop on Gravitation and Cosmology, Chinese University of Hong Kong, 14 – 20 August 2017
2. Introduction to GWs & PN approach (3 Lectures). Black Holes: From Classical to Quantum Gravity, IIT Gandhinagar, 15 – 19 December 2017
3. A set of three lectures on Pulsars and gravitational waves. Pulsar Astronomy with uGMRT Boot-Camp and Multi-Wavelength Neutron Star Workshop, BITS-Pilani, Hyderabad Campus, 03 – 08 January 2018

T. P. Singh
1. Is quantum theory exact, or approximate? Colloquium, IISER Mohali, February 12, 2018
Department of Biological Sciences

Mithilesh Mishra
Contractile ring and the art of splitting the cell. International Workshop on Cellular Dynamics, Hokkaido University, Japan. May 17, 2017

Vidita Vaidya
1. Early Experience, 5-HT_{2A} receptors and programming of psychiatric vulnerability. Neuroscience across Scales, NCBS, July 2017
2. Norepinephrine and Thyroids Hormone: A tale of two tyrosine derived neurogenesis regulators. NMIMS Symposium, July 2017
4. Serotonin_{2A} receptors and the programming of psychopathology. Symposium talk, EBPS, Crete, Greece, Sep 2017
5. Serotonin_{2A} receptors and the programming of psychopathology. RCB Colloquium, Faridabad, October 2017
6. Serotonin and the development of psychopathology. GRC, Kochi, December 2017
7. Serotonin and the Programming of Psychiatric Vulnerability. IBRO-APRC School, University of Pune, March 2018

Department of Chemical Sciences

Iyotishman Dasgupta
Resonance Raman Spectroscopy. Invited Teaching Talks (1 and 2 for 3 hours), FCS2017 meeting, IIT Guwahati, December 2017

Mamata Joshi
NMR: Applications in Biology. Foundation for Medical Research, Worli, Mumbai, 24 August, 2017

Deepa Khushalani
1. What are Nanomaterials and why are they important. NCNNMU, University of Mumbai, March 2018
5. Moderator for Panel Discussion – Trends and Skill set requirements for Chemical Industry. ChemCareers India, RSC Event, Vaze College, September 2017
6. Fundamental Chemistry and its use in Advanced Research. RSC Workshop, IGNOU, Nagpur, July 2017

A. S. R. Kati
Stability, unfolding and folding of SUMO proteins. DCS Annual Talks, November 29, 2017, TIFR, Mumbai

Sudipta Maiti
1. Light Microscopy. BAW 2018, Gangtok, India, Feb. 2018
6. What withers us? The Biophysics of Protein Aggregation. Faculty Development Talk, IIT Dhanbad, June 9, 2017

Department of Condensed Matter Physics and Material Sciences

Venu Gopal Achanta
2. Quantum Optics in solid state systems. DST-SERB School on Frontiers in Quantum Optics IIT, Guwahati, 1–19 December 2017

Arnab Bhattacharya
2. Seeking N-lightenment – one cup at a time! INSA Award lecture, IISER Pune, Dec. 27, 2017; also at Centre for Excellence in Basic Sciences, Mumbai, Oct. 3, 2017; IIT-Patna, First year colloquium, Aug. 8, 2017
3. GaN and GaP based nanowires: from growth mechanisms to device structures. Institute of Solid-State Physics, Technical University-Berlin, May 19, 2017
4. III-Nitrides, 2D Materials, 1D Nanowires: A zeroth order summary of semiconductor optoelectronics at TIFR. University of Münster, May 12, 2017

S. S. Prabh
“Tera-Overview On The Tera-Hertz (THz) Radiation
Properties, Applications And Challenges” and “Tera-Hertz (THz) Sources And Detectors Fabrication and Optimization”. QIP Short Term Course cum Workshop on “Industrial Application of THz Radiation”, IIT Kharagpur, 27 March–04 April 2017

S. Ramakrishnan
1. Superconductivity in Bi. TCIS, TIFR-Hyderabad, April 2017
2. Superconductivity of metals. Past, Present and Future (3 lectures). UGC-DAE Centre, Indore, August 2017
4. Discovery of superconductivity of very pure single crystal of Bismuth. Anil Kumar Memorial Lecture, I.I.Sc., Bangalore, Nov. 2017

P. K. Mohanty

G. Ravindra Kumar
Quantum Optics, Lasers and Nonlinear Optics. Master’s 5th year course, PE1013, UM-DAE Centre for Excellence in Basic Sciences, Mumbai, Jan – April 2017

Deepankar Misra
TIFR graduate school: Atomic and Molecular Physics, August 2017

Sushil Mujumdar
Anderson localization and Levy sums in random lasers. Symposium 20 years of Nano-optics. Max Planck Institute for the Study of Light, Erlangen, Germany. 20 Sep 2017

E. V. Sampathkumaran
1. Spin-chain and geometrically frustrated magnetism and magnetoelectric coupling. SRM University, Chennai, 12 December 2017
2. Magnetism and magnetoelectric coupling behavior in Haldane spin-chain family, $R$BaNiOs ($R$= Rare-earths). IISER Trivandrum, 16 Feb. 2018

A. Thamizhavel
1. Lecture series on Crystal Growth. DST-SERC school on Radiation detector materials and its applications, SSN College, 23 Aug to 12 Sep. 2017
3. Anisotropic magnetic behavior and quantum criticality in Ce-based intermetallic compounds. MRSI Trichy Chapter, Bharathidasan University, 14–16 Feb. 2018

Department of High Energy Physics

P. K. Mohanty

Department of Nuclear and Atomic Physics

G. Ravindra Kumar
Quantum Optics, Lasers and Nonlinear Optics. Master’s 5th year course, PE1013, UM-DAE Centre for Excellence in Basic Sciences, Mumbai, Jan – April 2017

Deepankar Misra
TIFR graduate school: Atomic and Molecular Physics, August 2017

Sushil Mujumdar
Anderson localization and Levy sums in random lasers. Symposium 20 years of Nano-optics. Max Planck Institute for the Study of Light, Erlangen, Germany. 20 Sep 2017

R. Palit
1. Nuclear structure studies with gamma spectroscopy (4 lectures). RCNP, Osaka University, Japan during 2 – 3 Feb 2017

L. C. Tribedi
1. TIFR-graduate course: Atomic collisions Aug–Dec, 2017
2. Series of lectures in SERC schools in TIFR (6 lectures)
3. DST SERC school, RKM Kolkata (14 lectures)

Department of Theoretical Physics

Amol Dighe
1. Neutrino Physics, SERC School in Experimental High Energy Physics, NISER Bhubaneswar, Dec 2017

Sourendu Gupta
1. Open problems in High Energy Physics. EHEP SERC School, NISER Bhubaneshwar, 13 Nov 2017
2. Globalization of Ideas. Xavier’s Berkeley Program, St Xavier’s College Mumbai, 28 July 2017

Gautam Mandal
Introduction to Quantum Field theory. Shizuoka University, Shizuoka, Japan, November 3–7, 2017

Nilmani Mathur
Particle Physics. Centre for excellence in Basic Sciences, University of Mumbai, 2017

Shiraz Minwalla
1. The AdS/CFT Correspondence. Bangkok School on High Energy Physics, July 2017
2. Supersymmetric Gauge Theories. Asian Winter School, ICTS Bangalore, January 2018

Sreekantan Raychaudhuri
2. Higgs Physics. Pre-SUSY-17 School, TIFR, Dec 2017
Tridib Sadhu
1. Macroscopic fluctuation theory. International summer school on Statistical Physics, ICTS-TIFR, Bangalore, 3–14 July 2017
2. Large deviation theory, TCIS, Hyderabad, 29 January – 2 February, 2018

Rajdeep Sensarma
Course on Non Equilibrium Field Theory, IACS Kolkata, 2018.

Research Facilities

Low Temperature Facility

K V Srinivasan
1. Course Lectures, Experimental Methods-II. INO Graduate School 2017 students, November 2017
2. Cryogenics: The science and engineering of the very cold. VSRP-2017, TIFR Mumbai, 8 June 2017

National Facility for High Field NMR

Mamata Joshi
NMR: Applications in Biology. Foundation for Medical Research, Worli, Mumbai, 24 August 2017

TIFR Centres

International Centre for Theoretical Sciences, Bengaluru

P Ajith
Physics and astrophysics of black holes and neutron stars.
HDM2017: International Workshop on Hot and Dense Nuclear and Astrophysical Matter, Stellenbosch University, South Africa, November–December, 2017

Subhran Bhattacherjee
1. Quantum spin liquids (4 lectures). School on frustrated magnetism, IMSc, Chennai, April 2017
2. Frustrated magnets (2 lectures). School for graduate students, Pilsen, September 2017

Chandan Dasgupta
1. Glass Transition in Dense Systems of Self-propelled Particles. State University of New York, Buffalo, September 2017
2. Glass Transition in Dense Systems of Self-propelled Particles, Indian Association for the Cultivation of Science, Kolkata, January 2018

Rakmini Dey
Geometric Quantization (3 Lectures). Workshop on J-holomorphic curves and Gromov-Witten invariants, NISER, Bhubaneswar, July 2017

Abhishek Dhar
1. Three preparatory lectures in Bangalore school on statistical physics, ICTS-TIFR, Bangalore, June–July 2017
2. Three lectures at SERB School on Frontiers in Quantum Optics, Department of Physics, IIT Guwahati, December 2017
3. Three lectures at School on Driven Quantum Systems, IACS, Kolkata, February 2018

Rajesh Gopakumar
1. Conformal Bootstrap, IISER-Pune, August 2017
2. Exact Methods in Low Dimensional Statistical Physics. Lectures at the Cargese Summer School, Institut d’Études Scientifiques de Cargèse (IESC Cargèse), Corsica, France, July–August, 2017
3. Seminar, University of Amsterdam, April 2017

Rama Govindarajan
1. MPIDS Colloquium, Max Planck Institute for Dynamics and Self-Organization, Goettingen, August 2017
2. Physics Department Colloquium, Indian Institute of Science, February 2018
3. Einstein lecture, Jain University, Bangalore, July 2017

Bala Iyer
1. The Rapid Leap from Gravitational Wave Detection to Multi-Messenger Astronomy. Distinguished BOSE-125 Lecture, S. N. Bose Centre for Basic Sciences, Kolkata, March 2018
2. The detection of gravitational waves and the two body problem in general relativity – A personal view. K L Memorial Distinguished Lecture, CMI, Chennai, January 2018
3. Chair, Panel Discussion on Ringdown, and Panel Member for Science drivers for 3G detectors: Fundamental Physics and Cosmology, PAX Nikhef, August 2017

Vijay Kumar Krishnamurthy
NCBS Monsoon School, IIT Gandhinagar, June 2017

Shashi Thutupalli
1. Department Seminar, MPI-CBG, Dresden
2. Department Seminar, MPI-PKS, Dresden
3. MPIDS Advances Talk, MPI-DSO, Goettingen
4. CeNS Colloquium, Ludwig-Maximilians University, Munich, Germany
5. Biology Colloquium, IMSc, Chennai
[6. Mechanical Engineering Department Seminar, Indian Institute of Science, Bangalore]

[7. NCBS-Simons Monsoon School, 2017]

[8. EMBO-NCBS Course on Experimental and Theoretical Approaches to Cell Mechanics, NCBS, Bangalore]

**National Centre for Radio Astrophysics, Pune**

**Bhattacharyya, Bhaskar**

1. Pulsars and transient. VSRP, NCRA Pune, June 2, 2017
3. Demonstration on pulsar timing analysis with real and simulated data. Radio Astronomy School, NCRA, Pune August 31, 2017
4. Introduction to experiment on detection of 21 cm signal using 4-m telescope and horn antenna. Radio Astronomy Winter school, NCRA, Pune Dec 18, 2017
5. Conducted experiment for detection of 21 cm signal using 4-m telescope. Radio Astronomy Winter school, NCRA, Pune, December, 18 – 22, 2017

**Kanekar, Nissim**

1. Do the Fundamental Constants change with time? National Institute of Science Education and Research, Bhubaneswar, March 2018
2. Do the Fundamental Constants change with time? Ashoka University, Haryana, March 2018
3. Do the Fundamental Constants change with time? Physics Department, S. P. Pune University, Pune, October 2017
4. Science with the Upgraded GMRT, TIFR Founder’s Day Colloquium, TIFR-Mumbai, October 2017
5. Do the Fundamental Constants change with time? Presidency University, Kolkata, October, 2017
6. Do the Fundamental Constants change with time? Vikram Sarabhai Award Colloquium, Physical Research Laboratory, Ahmedabad, June 2017

**Kharab, Prati**

1. Writing a GMRT Proposal. Radio Astronomy School at NCRA, 28 August – 8 September 2017
2. X-rays from AGN Jets. Chandra CIAO Workshop, NCRA, 23–27 October 2017

**Gupta, Yashwant**

1. Introduction to the GMRT. Radio Astronomy School, NCRA, Pune, August, 4 2017
2. The Square Kilometre Array Project. Tenth Radio Astronomy Winter School, NCRA, Pune, December 22, 2017
3. The upgraded GMRT: Opening new windows to the low frequency radio Universe. Max Planck Institute for Radio Astronomy, Bonn, Germany, November 7, 2017

**National Centre for Biological Sciences, Bengaluru**

**Deepa Agashe**

1. Bacterial genome evolution: Reconciling experiments and phylogeny. SMBE meeting, Austin, USA, July 2017
2. Laboratory of bacterial genome evolution. Summer school on Theoretical and Molecular Biology, Barcelona, Spain, 2017

**U. S. Bhalla**

1. Models and cellular biophysics. Cluj, Romania: Transylvania Experimental Neuroscience Summer School, 9–14 June 2017

**Axel Brockmann**

“Biology of Asian honey bees” and “Molecular mechanisms underlying daily foraging in honey bees”. Refresher Course for college lecturers, Department of Microbiology and Biotechnology, Bangalore University, 28 Feb 2018

**Sumanta Chattarji**

Foundation of Revitalization of Local Health Traditions (FRLHT), Nov 2017

**Ranabir Das**

NMR. IBAB, Bangalore, 2017

**Krishnamoorthy Kunte**

Eight lectures as part of the undergraduate-level training workshop in Molecular Biology, CRG, Barcelona, Spain, July–August 2017

**Rajesh Ladher**

On Mouse as a Model System. BSBE Winter Workshop, IIT Kanpur, 15 December 2018

**M. K. Mathew**

1. Lecture Workshop on Recent Advances in Biophysics, MACFAST, 15 and 16, June 2017
2. Asset Summer Programme for School Children, Manipal University, 15 – 18 May, 2017
3. IBRO Course in Neuroscience, Jakarta, Indonesia, July 12 – 20, 2017
4. Basic Neuroscience Series of Lectures, DBS, TIFR March 2017
5. The Heart of the Matter: the Mechanics of the Heart Affects its Electrical System. NISRT Bhubaneswar,
April 5, 2018

6. Coping with an Increasingly Saline World. NISER Bhubaneswar, April 6, 2018

Satyaigit Mayor
Summer Institute, Woodshole, USA. 16 Jun – 16 July, 2017

Shannon Olson
1. YETI Workshop, Tezpur
2. India BioScience Workshop for Undergrad. Faculty (Instructor, St. Joseph’s College)

Vinothkumar Katti Ragunath
Motor Systems, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, October 2017

P. V. Shivaprasad
1. Epigenetics and transcriptional silencing. Workshop for PG teachers, Crop Physiology, University of Agricultural Sciences, Bangalore, 9 March 2017
2. Epigenetics and small RNA variations in plants. Workshop on genomics, Department of Genetics, University of Agricultural Sciences, Bangalore, 17 March 2017
3. miRNA-mediated regulation of plant secondary metabolism. IISER Pune, 04 December, 2017
4. miRNA-mediated regulation of plant secondary metabolism. University of Hyderabad, 26 April, 2018
5. miRNA-mediated regulation of plant secondary metabolism. OMICS gateway-Tools and Techniques for Modern Agriculture, GKVK, 23 March 2018
6. Biogenesis and functions of plant small RNAs. Bangalore University, Workshop for PG teachers, 23 February 2018
7. Insights into miRNA biogenesis and their functions in plants. ‘Plant-Insect-Microbe interactions’ NCBS, December 17, 2017
8. Experimental approaches in utilization of genomic resources for improvement of horticultural crops. University of Horticultural Sciences, Bagalkot, 22 August 2017
9. Application of Biotechnology in Horticulture Use of small RNA molecules to remodel plant development and metabolism. Prof. M. H. Marigowda Memorial Lecture, Lalbagh, Bangalore, 22 June 2017

R. Sowdhamini
1. Aqua-Terr Annual Symposium, Madurai Kamaraj University, Feb 2018
2. National Workshop on Bioinformatics. Sri Venkateshwara University, Mar 2018

Varadharajan Sundararamu
1. The intersection of intracellular mycobacterial trafficking routes with host endocytic pathways. Xi’an Jiaotong-Liverpool University, Suzhou, China, April 2017
2. The intersection of intracellular mycobacterial trafficking routes with host endocytic pathways. Department of Biochemistry, University of Geneva, Switzerland, July 2017
3. The intersection of intracellular mycobacterial trafficking routes with host endocytic pathways. IGB, New Delhi, Feb 2018

Makund Thattai

Vatsala Thirmalai
Motor Systems, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur, October 2017

Shashi Thutupalli
1. Department Seminar, MPI-CBG, Dresden
2. Department Seminar, MPI-PKS, Dresden
3. MPIDS Advances Talk, MPI-DSO, Goettingen
4. CeNS Colloquium, Ludwig-Maximilians University, Munich, Germany
5. Biology Colloquium, IMSc, Chennai, India
6. Mechanical Engineering Department Seminar, Indian Institute of Science, Bangalore
7. NCBS-Simons Monsoon School, 2017
8. EMBO-NCBS Course on Experimental and Theoretical Approaches to Cell Mechanics, NCBS, Bangalore

Radhika Venkatesan
Mass Spectrometry in Ecology, Mass Spectrometry Course at CCAMP, Bangalore, Jan 2017

TIFR Centre for Interdisciplinary Sciences, Hyderabad

Dani, Adish
University of Hyderabad, School of Life Sciences, Seminar, March 2018

Karmaker, Smarajit
Soft and Active Matter Workshop, University of Hyderabad, Hyderabad, February, 2018

Madhu, P. K.
1. Observing Ab transition from monomers to oligomers to fibrils through the solid-state NMR looking glass. CCMB, Hyderabad, November, 2017
2. Winter school on hyperpolarisation, Two lectures on NV centres, Schloss Windischleuba, Leipzig, Germany, February, 2017
3. Robust magic-angle solid-state NMR methods for structure elucidation. University of Bayreuth, Germany, March, 2018

Mote, Kaustubh R.
Basics of NMR. Workshop ‘Insights into Biomolecular Interactions: A Biophysical Perspective’, Centre for Data Analytics and Research Guru Nanak Dev University, Amritsar, Punjab February, 2018

Naranganan, T. N.
1. Combining theory and experiment in electrochemistry. BTIS Pilani Hyderabad Campus, 21 February 2018
2. Combining Theory and Experiment in 2D Electrochemistry, National Seminar on “Theoretical and Experimental Approaches for Exploring Advanced Materials” (TEAM2017), Govt. Arts & Science College, Calicut, Kerala, 13 December 2017
Developments in Materials Science, Govt. Victoria College, Palakkad, Kerala 13 November 2017


7. Nanoscale Interfaces – A New Era of Materials Engineering, One day seminar on “Magnetic Research Advancements – 2017 (MRA-2K17)”, Department of Physics, Cochin University of Science and Technology, Kochi

Homi Bhabha Centre for Science Education, Mumbai

J. Advani & CUBE Team
CUBE model systems, Fabricated web-cam based microscope and citizen science activities. Savitribai Phule University, Pune, December 8, 2017

J. Advani, M. C. Arunan & CUBE Team
A session on CUBE activities on model systems like Moina. Awami Girls School, Deonar Colony, Mumbai, Jan 23, 2018

M. C. Arunan
Fruit fly and movie maker’s club activities. Handique Girls School, Guwahati, November 29–30, 2017

S. Chandrasekharan
1. The impossible optimization problem. Faculty seminar, IIM, Ahmedabad, September 14, 2017
2. The impossible optimization problem. Interdisciplinary Program in Educational Technology, Indian Institute of Technology, Bombay, September 26, 2017
3. Innovative teaching tools and technologies for engineering faculties. Vidyalankar Institute of Technology, Mumbai, June 19, 2017

S. Chandrasekharan, H. Agrawal and D. Karnam
Bringing the textbook to life: Dynamic and interactive simulations to support model-based imagination and reasoning. Interdisciplinary Program in Educational Technology, IIT, Bombay, September 19, 2017

S. Chunnawala
1. Curricular approaches to technology education. Two day National Level Seminar on Designing the 21st Century Classroom, Pillai College of Education and Research, Panvel, April 9, 2017
2. Project Based Learning (PBL) in the teaching and learning of humanities. Orientation Course for the Course Directors, Associate Course Directors and Resource Persons, KV-ZIET, Mumbai, April 21, 2017
3. Project Based Learning (PBL) in the teaching and learning of science. Orientation Course for the Course Directors, Associate Course Directors and Resource Persons, KV-ZIET, Mumbai, April 26, 2017
5. Gender and science, technology and education. N.E.S. Ratnam College of Arts, Science and Commerce, Mumbai, November 30, 2017
6. Qualitative research design. Seminar-cum-Workshop on Fundamentals of Research, Bombay Teachers’ Training College, Mahakavi Bhushan Road, Mumbai, Dec 6, 2017
7. Science and society interactions. NIUS camp for Chemistry, December 27, 2017

G. Date
Technology from the grassroots: What formal engineering can take away? Dialogue event “Science: From the grassroots to the laboratory” organized by the Indian Academy of Science in collaboration with IISER, Pune, February 25, 2018

G. Date and D. Dutta
Bringing imagination back in engineering education. Workshop on innovative teaching tools and technologies for engineering faculties, Vidyalankar Institute of Technology, Mumbai, June 19, 2017

N. D. Deshmukh
1. Assessment and evaluation and research methodology. YCMOU-PGRP workshop lectures, HBCSE, April 2, 2017 and December 17, 2017
2. Activity based and joyful EVS learning. Matoshri Vidya Mandir, Mankhurd, April 13, 2017
4. How does knowing about misconceptions in a bilingual context can help students learning: An Indian experience? The 91th National Association for Research in Science Teaching’s (NARST) 2018, The Westin Peachtree Plaza, Atlanta, GA, USA, March 10 – 13, 2018

N. D. Deshmukh and E. Nyamupangedengu
Investigating the impact of using the TSPCK framework on the content knowledge of in-service teachers: An exploratory case study. The SAARMSTE 2018 Conference, University of Botswana, Gaborone, January 16–19, 2018

D. Dutta and S. Chandrasekharan
Humus and humility: Situated and embodied interactions constitute a lived morality towards the environment. 7th EcoJustice and Activism Conference, College of Education Porter Building, Eastern Michigan University, March 8–10, 2018

A. Gupta
1. Course on environmental science. Semester 5 course for undergraduate students of UM-DAE CEBS, Mumbai, October–November, 2017
2. How can we use simple materials to generate rich learning situations? 25th National Children’s Science Congress 2017, Ahmedabad, December 29, 2017

D. Gupta
Using longitudinal research data to build a teaching case: An example: Greenland inuits: a curious lifestyle paradox (Poster Presentation). Annual International Conference on Case Study Teaching, Buffalo University, USA, NSTA, Sep 5, 2017

P. K. Joshi
1. Physics: Classical to modern approach. XVIII JSO & JMO 2017, Atomic Energy Junior College, Mumbai, October 9, 2017
2. Science Olympiad. Rajendra Prasad Science Centre, Nagpur, November 16–18, 2017
A. Kanhere
2. Numbers and their operators. For students of MA Education in elementary studies as part of Pedagogy of Mathematics Education Course, Tata Institute of Social Sciences, Mumbai, October 30, 2017

R. Khaparde
1. Improving teaching and learning in science. Cathedral and John Connon Secondary School, Mumbai, April 5, 2017
3. What is experimental problem solving? Ashoka University, Sonepat, Haryana, September 9, 2017
4. Opportunities for students under the National Initiative on Undergraduate Science. IAPT National Convention and National Symposium on Recent Trends in Physics at Different Scales, Gurukul Kangri Vishwavidyalaya, Haridwar, October 31, 2017
5. Opportunities for students under the National Initiative on Undergraduate Science. SGRR PG College, Dehradun, November 2, 2017
6. Training in experimental physics. IAPT RC5, LMS Govt. PG College, Rishikesh, November 3, 2017
7. Introduction to physics through experiments. Course conducted for students from Ashoka University, January–March 2018

M. Kharatmal, J. Advani & CUBE Team
Innovative teaching-learning methods in science. Ratnam College, Bhandup, November 28, 2017

A. Mazumdar
1. One semester course on “Optics”, UM-DAE CEBS, Mumbai, January–April, 2017
2. One semester course on “Classical Mechanics”, UM-DAE CEBS, Mumbai, August–November, 2017
3. One semester course on “Classical Mechanics”, UM-DAE CEBS, Mumbai, January–April, 2018

K. K. Mistra
2. Science in Indian literature. International Symposium on Science and Literature, Birla College, Kalyan, January 12–13, 2018

A. Muratidhar
Environment friendly lifestyles. Guest lecture, BMN College, Matunga, February 26, 2018

G. Nagarjuna
1. Activity based collaborative distributed engagement. ABCDE workshop, Department of Education, University of Mumbai, August 2, 2017
2. Learning teaching through sustained engagement through instant feedback. ABCDE workshop, Department of Education, University of Mumbai, August 2, 2017
3. Ethical basis of digital freedom. Guest lecture, CEBS, Kalina, University of Mumbai, March 7, 2018

G. Nagarjuna and M. C. Arunan
1. Evolution: Why do we get it wrong? Ruparel college, February 18, 2018
2. Was Darwin wrong? Bluestar employees association, March 27, 2018

G. Nagarjuna, O. Manzoor, M. Dutta and K. Anurag
Panel discussion on STEM education in India. Organized by Asia Society, Nehru Centre, Mumbai, March 1, 2018

S. Naik
1. Mathematics through graphs. XVIII JSO & JMO 2017, Atomic Energy Junior College, October 12, 2017
2. Fractions, ratios and proportional reasoning. For students of MA Education in Elementary studies as part of Pedagogy of Mathematics Education Course, Tata Institute of Social Sciences, Mumbai, October 31, 2017
3. Measurement at early grades. For students of MA Education in Elementary studies as part of Pedagogy of Mathematics Education Course, Tata Institute of Social Sciences, Mumbai, November 1, 2017
4. Listening to students for equal access in mathematics. The 8th International Conference of Comparative Education Society of India on Criticality, Empathy and Welfare in Contemporary Educational Discourses, Jammu, November 16–18, 2017
5. Pedagogical Content Knowledge for teaching mathematics at secondary level. For PGT teachers of Kendriya Vidyalaya organised by Zonal Institute of Education and Training of Kendriya Vidyalaya Sanghathan, KV-Bhandup school, January 1, 2018

S. Naik & N. Sharma
Teacher education and preparation. For students of MA Education in Elementary studies as part of Pedagogy of Mathematics Education Course, Tata Institute of Social Sciences, Mumbai, November 7, 2017

C. Navare
Visuals in biology: Motion and agency. Annual Meeting of the Society for Social Studies of Science (4S), Boston, USA, September 1, 2017

S. Pathare
Indian National Olympiad Program and its Contribution to Undergraduate Education. The 8th Congress of World Federation of Physics Competition, Vienna, Austria, February 20–24, 2018

H. C. Pradhan
Course on ‘Ethics in science and intellectual property rights’. For students of the Integrated M.Sc. Programme, UM-DAE CEBS, January–April 2017

P. Ramadive
Astronomy for beginners; Telescope handling assembly and sky observation. Workshop on “Observational Astronomy”, organized collaboratively by Science Teachers Association (STA-J&K), Department of School Education (J&K) and Vigyan Prasar (New Delhi), Srinagar, March 25–26, 2018
H. Raiwal
1. Analyzing students’ errors: Examples from geometry and measurement. ZIET-Mumbai, August 2, 2017
3. Twisting the untwisted: Mathematical space, St. Xavier’s college, Mumbai, January 20, 2018

V. C. Sonawane
2. Project based learning, Rayat Sarshta, Ramnath Thakur English School, Kamothe, November 18, 2017
3. Career opportunities and future prospects, Ideal High School and Junior College, Trombay, Mumbai, November 25, 2017
4. Vidyan shahityache Marathi sabhityatil yogdan, J. P. Naik College of Science and Arts, Nashik, December 29, 2017

H. Srivastava and A. Ravendran
Waste as a context for justice-oriented science education. The 12th Conference of the European Science Education Research Association, Dublin, Ireland, August 23, 2017

H. Srivastava and T. Khan
Analysing classroom discourse on waste from the standpoint of urban poor. The 12th Conference of the European Science Education Research Association (ESERA), Dublin, Ireland, August 21, 2017

G. Stachowski and A. Sale

K. Subramaniam
1. Exploring integer meaning in contexts. Workshop session at the Annual Conference of Association for Mathematics Education of South Africa, Nelson Mandela University, Port Elizabeth, July 6, 2017
2. Supporting teachers in making sense of students’ mathematics. IMSc, Chennai, February 2, 2018

A. Sule
2. Lecture on number theory. AECS JSO/JMO camp, October 12, 2017
3. Coordinate system; Moon activity of Vigyan Pratibha; Olympiads Overview. Workshop on “Observational Astronomy”, Science Teachers Association (STA-J&K), Department of School Education (J&K) and Vigyan Prasar (New Delhi), Srinagar, March 25–26, 2018

A. Sule and P. Adekar
Course on Introductory mathematics-2 (M200). UM-DAE CEBS, Mumbai, January–April 2018

A. Sule and S. Naik
Course on Introductory mathematics-1 (M100). UM-DAE CEBS, Mumbai, August-November, 2017

S. Takker
Developing noticing in middle school mathematics teachers. The 8th International Conference of Comparative Education Society of India on Criticality, Empathy and Welfare in Contemporary Educational Discourses, Jammu University, November 16-18, 2017

R. Varkey
Are farmers scientists? Changing conceptions of the nature of science in Kerala textbooks. The 12th Conference of the European Science Education Research Association (ESERA), Dublin, Ireland, August 24, 2017

R. Vartak and A. Raiwal
Investigations in the biochemistry lab: An opportunity to enhance student engagement with method of science and procedural understanding. The New Horizons in Biochemistry and Molecular Biology Education Conference, Weizmann Institute of Science, Israel, September 6-8, 2017
Lectures, Colloquia, Seminars at TIFR

Lectures by Visitors

School of Mathematics

Tadashi Ochiai (Osaka University, Japan) Iwasawa theory for $p$-adic family of modular forms (12.05.2017)
Rahul Singh (Northeastern University, USA) Conormal Varieties on the Cominuscule Grassmannian (14.06.2017)
Madhav Nori (University of Chicago, USA) Semi-Abelian Motives (10.07.2017)
Prakash Belkale (University of North Carolina, USA) Extremal rays and vertices in eigenvalue problems (18.07.2017)
Ryotaro Harada (Nagoya University, Japan) On Euler’s methods for double zeta values (21.07.2017)
Thomas Koberda (University of Virginia) Right-angled Artin groups and their subgroups (04.08.2017)
Krishna Athreya (Iowa State University, USA) Ergodic Theorems for regenerative sequences (04.08.2017)
Amod Agashe (Florida State University, USA) The curve and the local Langlands correspondence (05.01.2018)
Akshaa Vatwani (University of Waterloo, Canada) Moments of the divisor function (08.08.2017)
Kartik Prasanna (University of Michigan, USA) Conformal blocks and verlinde formula (16.01.2018)
Madhav Nori (University of Chicago, USA) Varieties on the Cominuscule Grassmannian (28.03.2018)
Rahul Singh (University of North Carolina, USA) On double zeta values (31.01.2018)
Aditya Karnatak (Beijing International Center for Mathematical Research, People’s Republic of China) $\pi^f$-modules (20.01.2018)
Wilfried Schmid (Harvard University, USA) Comparison of the Langlands-Shahidi and Bump-Friedberg lifts for GL(n) (24.01.2018)
R. S. Kannan (University of North Carolina, USA) On double zeta values (31.01.2018)
Shrawan Kumar (University of North Carolina, USA) Conformal blocks and Verlinde formula (16.01.2018)

TIFR Centre for Applicable Mathematics, Bengaluru

J. Krishnan (Imperial College, London) Dissecting and engineering information processing at multiple levels in cellular networks (April 7, 2017)
Anupam Pal Choudhury (Darmstadt University of Technology) Isakov’s reflection technique for partial data inverse problems and some applications (May 4, 2017)
Naveen Garg (Department of Mathematical Sciences, IIT, Kanpur) A Novel upwind method for genuinely weakly hyperbolic systems and its application to Euler equations (June 2, 2017)
Sanjayan Sen (McGill University, Canada) Random
structures: Phase transitions, scaling limits, and universality (June 7, 2017)
Sun-Sig Byun (Seoul National University) Higher integrability results for elliptic and parabolic problems with nonstandard growth (June 12, 2017)
Ramesh Manna (Harihar-Chandra Research Institute, Allahabad) On local smoothing of Fourier integral operators (June 19, 2017)
Karthik Adimurthi (Seoul National University) Boundary higher integrability for very weak solutions of quasilinear parabolic equations (June 23, 2017)
Jyothi Krishnan (University of California, Berkeley) On the mechanics and mathematical analysis of fiber-reinforced media (June 30, 2017)
Ali Hyder (Department of Mathematics and Informatics University of Basel, Switzerland) Conformal metrics on R^n with arbitrary total Q-curvature (July 13, 2017)
Apala Mazumdar (University of Bath, UK) Uniaxial versus Biaxial Character of Landau-de Gennes Minimizers in Three Dimensions (June 21, 2017)
Nguyen Cong Phuc (Louisiana State University, Baton Rouge) The Navier-Stokes equations: stationarity, conditional regularity, and self-similar singularities (Lecture 1) (July 26, 2017)
Nguyen Cong Phuc (Louisiana State University, Baton Rouge) The Navier-Stokes equations: stationarity, conditional regularity, and self-similar singularities (Lecture 2) (July 27, 2017)
Sanjib Kumar Acharya (The LNM Institute of Information Technology, Jaipur) A priori error analysis of the hp-Mortar FEM for elliptic and parabolic problems (August 2, 2017)
Naoto Kumanogo (Kogakuin University, Japan) Phase space Feynman path integrals of higher order parabolic type with general functional as integrand (August 3, 2017)
Peechush Singh (IIT, Kanpur) Some class of iterative TVD scheme for solving variational inequality appear in Elasto-hydrodynamic lubrication problems (September 8, 2017)
Christian Klingenberg (University of Wuerzburg) Progress on the well-posedness theory of the multi-dimensional Euler equations (September 28, 2017)
Arijit Hazra (University of Gottingen, Germany) Numerical Simulation of Bloch Equations for Dynamic Magnetic Resonance Imaging (October 11, 2017)
Stefano Bianchini (SISSA, Trieste, Italy) A uniqueness result for the decomposition of vector fields in R^d (December 11, 2017)
Stefano Bianchini (SISSA, Trieste, Italy) On the structure of L\infty-entropy solutions to scalar conservation laws in one-space dimension (December 12, 2017)
Ananta K. Majee (University of Tubingen, Germany) On Stochastic Optimal Control in Ferromagnetism (January 2, 2018)
Deep Ray (MCSS, Ecole Polytechnique Federale de Lausanne, Switzerland) An artificial neural network for detecting discontinuities (January 4, 2018)
Sairam Kaliraj (ISI, Chennai) Harmonic Mappings and Harmonic Hardy Spaces (March 1, 2018)
Debanjana Mitra (IIT Bombay) Applications of microlocal analysis to the control theory (March 5, 2018)
Ram Baran Verma (IIT, Gandhinagar) Studies on the existence of positive solutions to fully nonlinear elliptic equations (March 7, 2018)
Koushik Ramachandran (Oklahoma State University, USA) Equidistribution of zeros of Random orthogonal polynomials (March 8, 2018)
Santanu Koley (DA-IICT, Gandhinagar) Integral equation techniques for wave-structure interaction problems (April 6, 2018)
Aiyappan Srinivasan (Department of Mathematics, IISC) Unfolding operators for general oscillating domains and Homogenization (April 26, 2018)

Lecture Series

Mokshay Madiman (University of Delaware) Forward and reverse entropy power inequalities (April 3 & 5 2017)
Govind Menon (Division of Applied Mathematics, Brown University, USA) An introduction to the Boltzmann equation (July 25 & 26 2017)
John Lewis (University of Kentucky) The best of Lewis (October 4, 5 & 10, 2017)
Fabrice Baudoin (University of Connecticut) Geometric inequalities on sub-Riemannian manifolds (January 19, 2018)

Special Lecture

Bernd Kawohl (University of Colango, Germany) On buttons and balls that cannot run away (November 8, 2017)

School of Natural Sciences

Department of Astronomy and Astrophysics

Deepto Chakrabarty (Massachusetts Institute of Technology, USA) Early Results from NICER Observations of X-ray Binaries (February 27, 2018)
Thomas Henning (MPIA, Heidelberg) From protoplanetary disks to planetary atmospheres (21 November 2017)
Thomas Henning (MPIA, Heidelberg) Physics of Star Formation (22 November 2017)

Public Lecture

Frank Shu (University of California at Berkeley and San Diego) Two Planets: Challenges of Living and Prospering on Earth and Mars (15 December 2017)
Department of Biological Sciences

Kedar Natarajan Investigating the interplay between cell cycle and gene expression (15th May 2017)
Anup Padmanabhan Beyond Cell Adhesion – Uncovering Non-canonical Functions of E-cadherin (30 May 2017)
Sabari Sankar Thirupathy Collisions between Replication and Transcription Machineries (26 April 2017)
Rishikesh Narayan an (12th May 2017)
Neil Davey & Mirai Shah (25th May 2017)
Sandip Kaledhonkar Visualizing Translation Initiation in Real time by Time-resolved Cryo-EM technique (6th July 2017)
Andrej Sali Integrative modeling of biomolecular assembly structures and pathways (24 July 2017)
Avin Ramaiya Kinesin: A machine or an animal. A single molecule force spectroscopy approach (6 September 2017)
Palani SaraVanan Motor Activity Dependent and Independent Functions of Myosin II Contribute to Actomyosin Ring Assembly and Contraction (18 September 2017)
Jennifer Ross Weak, Transient Interactions Cause Strong Coupled Effects (21 September 2017)
Kavita Babu Post-synaptic receptor maintenance: The role of Claudins at the C. elegans Neuromuscular Junction (12 October 2017)
Swapnil V. Ghodge Discovery and Engineering of Enzyme Activities In Pursuit of New Antibiotics (26 October 2017)
Paul Janney Control of actin assembly by polyphosphoinositides (27 October 2017)
Gohta Goshima Microtubules and motors in plants (2 November 2017)
Anatoly Kolomeisky Understanding Molecular Mechanisms of Biological Error Correction (6 November 2017)
Ullas Kolthur Dynamic cortical binding promotes RhoA flux to effectors for cellular contractility (13 December 2017)
Srikanth Budnar (22 December 2017)
Abhishek Banerjee Ancestral imprints on descendant neurobiology (27 December 2017)
Brian Dias Role of G9a methyltransferase in skeletal myogenesis and rhabdomyosarcoma (3 January 2018)
Reshma Taneja The involvement of host- and parasite-cytoskeletal elements in malaria egress, invasion and intracellular division: New insights from conditional genetics and super-resolution imaging (8 January 2018)
Sujaan Das Linking epithelial cell polarity with embryonic neurogenesis - the Crumbs-Notch connection (16 Jan 2018)
Elisabeth Knust Leica Microsystems CMS GmbH (22 January 2018)

Department of Chemical Sciences

Malay Patra (University of Zurich, Switzerland) Improving Properties of Platinum Anticancer Drugs (April 6, 2017)

Malay Patra (University of Zurich, Switzerland) Discovery and Development of a New Class of Metal-Based Antibacterial
Compound (April 7, 2017)

Ramakrishnan Natesan (University of Pennsylvania, USA) Curvature remodelling of cell membranes: from the biochemistry to the biophysics (April 11, 2017)

Ramakrishnan Natesan (University of Pennsylvania, USA) Biophysics of the specific adhesion of nano-sized particles to cell membranes (April 12, 2017)

Dimpy Kalia (Savitribai Phule Pune University, Pune) Efficacious strategies for cysteine-mediated protein bioconjugation (April 20, 2017)

Dimpy Kalia (Savitribai Phule Pune University, Pune) Leveraging organic chemistry for solving biological problems: Bioconjugation and bacterial signaling as case studies (April 21, 2017)

Venkatesan Rajalingam (University of Maine, France) Nanostructured Materials for Photo-catalysis (April 27, 2017)

Aparna S. Deshpande (National Environmental Engineering Research Institute, Nagpur) Nanomaterials for Energy Application (May 9, 2017)

Leena George (National Chemical Laboratory, Pune) Surface Modified ZnO Nanostructures: Synthesis, Optical Studies and Applications in Photocatalysis (May 9, 2017)

Debananda Mohapatra (Indian Institute of Technology, Bombay) Designing Carbon-Metal Oxide Nanostructures for Energy Applications (May 30, 2017)

Asim Tewari (Indian Institute of Technology, Bombay) Tessellation Models for Microstructure Evolution (July 3, 2017)

Debdas Ray ( Shiv Nadar University, UP) Modulation of emission signaling pathway through allosteric control on the conformational rigidity of coumarin-imidazole conjugate (July 17, 2017)

Debasis Sen (Bhabha Atomic Research Centre, Mumbai) Integrity During Crisis in Colloidal Droplets (July 31, 2017)

Kalyan Chakrabarti (Max Planck Institute of Biophysical Chemistry, Germany) Conformational selection in a protein-protein interaction (August 2, 2017)

Kalyan Chakrabarti (Max Planck Institute of Biophysical Chemistry, Germany) The role of conformational dynamics in molecular recognition (August 3, 2017)


Anupam Bandyopadhyay (Massachusetts Institute of Technology, USA) Application of Iminobororane in Chemistry and Biology (September 14, 2017)

Anupam Bandyopadhyay (Massachusetts Institute of Technology, USA) Nonribosomal Polyamides Binder Discovery of Ebola Glycoprotein and Development of a Platform for Peptidomimetic Covalent Binder Discovery (September 15, 2017)

Peter Comba (University of Heidelberg, Germany) Coordination Chemistry of Cyclic Peptides: Possible Biological Functions of thePatellamides (September 18, 2017)

Shachi Gosavi (National Centre for Biological Sciences, Bengaluru) A tale of two proteins: What folding dynamics can tell us about the function of structurally similar proteins (September 25, 2017)

Paramita Haldar (Indian Institute of Technology, Bombay) Molecular Simulation of Long Time Structural Evolution in Nanomaterials (September 26, 2017)

Sanjay B. Kokane (Savitribai Phule Pune University, Pune) Development of Heterojunction Based Photocatalysts for Hydrogen Evolution Reaction and Dye Degradation Applications (October 12, 2017)

Basudev Maity (Tokyo Institute of Technology, Japan) Structural Aspects of Ferritin Protein Cage for Designing Inorganic Biomaterials (October 16, 2017)

Paul Janmey (University of Pennsylvania) Control of Actin Assembly by Polyphosphoinositides (October 27, 2017)

T.G. Ajithkumar (CSIR - National Chemical Laboratory, Pune) Insights into the mechanical properties of polymers by probing their functional group, and segmental motions using solid-state NMR. (October 30, 2017)

Gouriprasanna Roy (Shiv Nadar University, UP) Chemical Detoxification of Neurotoxic Methylmercury by Smart Molecules (November 8, 2017)


Mriganka Das (Indian Institute of Technology, Indore) Studies on Transition Metal Complexes of Flexible Polydentate Schiff Base Ligands (November 23, 2017)

Richard W. Kriwicki (St. Jude Children’s Research Hospital, USA) Exploring the Diverse Conformations and Biological Functions of IDPs (December 1, 2017)

Zeev Gross (Technion – Israel Institute of Technology) Energy Relevant Processes Catalyzed by Corrole Metal Complexes (December 7, 2017)


Jer-Lai Kuo (Institute of Atomic and Molecular Science, Academia Sinica, Taipei, Taiwan) Computational Material Design of Two Dimensional Materials and Their Energy Applications (December 14, 2017)

Ron Naaman (Weizmann Institute, Israel) The electron’s spin and molecular chirality - How are they related and how can they be utilized? (December 21, 2017)

Indrajit Ghosh (Max Planck Institute of Colloids and Interfaces, Germany) Stable Radical Anions in Photocatalysis (January 4, 2018)

Indrajit Ghosh (Max Planck Institute of Colloids and Interfaces, Germany) Making and Breaking of Chemical Bonds with Visible Light (January 5, 2018)

Hemakesh Mohapatra (Institute for Molecular Engineering, University of Chicago) Mechanoochemical strengthening of polymeric materials using piezoelectric nanoparticles (January 23, 2018)

Hemakesh Mohapatra (Institute for Molecular Engineering, University of Chicago) From destructive to constructive – Using energy to strengthen polymeric materials (January 24, 2018)

Amnon Horovitz (Weizmann Institute of Science, Israel) Chaperonin nano-machines: allostery and function (January 25, 2018)

Amnon Horovitz (Weizmann Institute of Science, Israel) Chaperonin nano-machines: allostery and function (January 25, 2018)

Amnon Horovitz (Weizmann Institute of Science, Israel) Chaperonin nano-machines: allostery and function (January 25, 2018)

Shang Kyu Kim (Korea Advanced Institute of Science & Technology, Korea) Nonadiabatic Reaction Dynamics at Conical Intersection (February 13, 2018)

Rahul Deshmukh (Cith University of New York) Breaking the RET barrier using metamaterials (February 19, 2018)

Raghunathan Ramakrishnan (TIFR Centre for
Department of Condensed Matter Physics and Material Sciences

Faraz A. Inam (Department of Physics, Aligarh Muslim University, Aligarh) Characterisation of nanodiamond nitrogen-vacancy (NV) centres spontaneous emission as a single photon source (April 4, 2017)

Ravi P.N. Tripathi (Research Fellow, Department of Physics, IIT, Roorkee, Roorkee) Nanophotonics of Organic Molecular Waveguides: Towards Active Optical Antenna (April 25, 2017)

Anil Jain, (Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai) Higgs (Amplitude) mode in a two-dimensional antiferromagnet (April 23, 2017)

Jyoti Sharma (Research Associate, Department of Physics, I.I.T. Bombay, Mumbai) Investigation of the magnetic, exchange bias and magnetocaloric properties in certain Mn-Ni based full Heusler systems (May 4, 2017)

Soham Manni (Department of Physics and Astronomy, Iowa State University, USA) Magnetically frustrated ground states in insulators and metals (May 5, 2017)

Phani Kumar (University of Basel, Switzerland) Sensing magnetic and stress fields with optically addressable nitrogen-vacancy spins in diamond (May 23, 2017)

Ramesh G. Mani (Department of Physics and Astronomy, Georgia State University, Atlanta, USA) Zero-resistance states induced by electromagnetic wave excitation in the high mobility GaAs/AlGaAs 2D electron system (May 31, 2017)

Himanshu Lohani (Ph.D. Student, Institute of Physics, Bhubaneswar) Band Structure of Topological Insulator Bi2Te3, Sb2Te3 (June 6, 2017)

Elaine T. Dias (Department of Physics, University of Goa) Unraveling the intricate mechanism of magnetoelastic coupling in Mn2GaC type Antiperovskite materials (June 9, 2017)

D. Krishnamurthy (SHANAN Innovatek Ventures, Chennai) Ga2O3 Properties, and prospects (June 13, 2017)

Bivas Saha (Department of Materials Sci & Engg., University of California, USA) Metal/Semiconductor Superlattices: Promise for a New Paradigm in Solid-State Energy Conversion (July 11, 2017)

Nicolas Roch (Institut Néel, CNRS and Université Grenoble, France) Circuit-QED based spectroscopies of quantum impurities (August 1, 2017)

Bidisha Roy (Walter Schottky institute of TUM, Munich, Germany) Nanoplasmonic array induced modified emission properties from monolayer WS2 (August 16, 2016)

Harish Krishnamoorthy (Nanyang Technological University, Singapore) Novel material paradigms for nanophotonics – from topological insulators and perovskites to chalcogenides (August 21, 2017)

Biplab Bag (Department of Physics, Indian Institute of Technology Kanpur) Investigation of doping dependent interplay between magnetic and superconducting order in BaFe2Co1.5As2 single crystals (August 22, 2017)

Yalla Ramachandraprasad (Research Assistant Professor, University of Electro Communications, Japan) Cavity Enhanced Spontaneous Emission for Single Quantum Emitters on a Nanofiber (August 28, 2017)

Shamshad Sengupta (Centre de Sciences Nucléaires et de Sciences de la Matière, CNRS/Université Paris-Saclay, Orsay, France) Non-equilibrium properties of a superconducting two-dimensional electron gas (August 28, 2017)

Vivek Mishra (Argonne National Laboratory, USA) Impurity scattering: A phase-sensitive probe of the superconducting order (September 19, 2017)

Iliaria Maccari (Senior Graduate, Sapienza University, Rome) Brezinski-Kosterlitz-Thouless transition indissordered superconducting films (September 20, 2017)

Kalon Gopinadhan (Department of Physics & Astronomy, University of Manchester, UK) Artificial Λ-scale fluids (September 25, 2017)

Kalon Gopinadhan (Department of Physics & Astronomy, University of Manchester, UK) Two-dimensional van der Waals materials based designer fluidic channels (September 26, 2017)

Sanjay Kumar Upadhyay, (Visiting Post-doctoral Fellow, DCMPE@MS, T.I.F.R., Mumbai) Magneto-electric coupling effect in spin-chainoxides (September 6, 2017)

Anamaya Sengupta, (Department of Physics, I.I.T., Delhi) Optics in Material Science: From Ultra-Fast timescales to Ultra-High Pressures (October 3, 2017)

Dipankar Jana (Homi Bhabha National Institute, RR-CAT, Indore) Spectroscopic Characterization of MBE grown AlGaN/GaN Heterostructures (October 17, 2017)

Subhasish Mandal (Post-doctoral Associate, Department of Applied Physics, Yale University) First principles investigation on Quantum Materials (October 3, 2017)

Subhasish Mandal (Post-doctoral Associate, Department of Applied Physics, Yale University) Towards highly scalable GW calculations (October 4, 2017)

Dai-Sik Kim (Centre for Angstrom Scale Electromagnetism, Department of Physics and Astronomy, Seoul National University, Korea) Tunneling rectification through macroscopic rings of nano barriers (October 5, 2017)

Mounima Nandi (Saha Institute of Nuclear Physics, Kolkata) Study of different physical properties of some quasi-one-dimensional spin chain compounds (October 6, 2017)

Bodhadipta Santra (Center for Optical Quantum Technologies, University of Hamburg Germany) Cold atom quantum
technology (October 31, 2017)

Bodhadiya Santra (Center for Optical Quantum Technologies, University of Hamburg, Germany) Exploring many-body quantum dynamics with ultracold atoms in optical lattices (November 2, 2017)

Venkat Chandrasekhar (Northwestern University, USA) Superconductivity, Magnetism, Anisotropy and Memory: The Remarkable Properties of the Conducting Gas at the (111) LaAlO3/SrTiO3 Interface (November 20, 2017)

Necer Guar (Max Planck Institute of Microstructure Physics, Germany) Magneto-thermopower in semimetallic WTe2; thin flakes (November 28, 2017)

Deep Jariwala (California Institute of Technology, USA) Heterostructures for Nanoelectronics and Photovoltaics (December 7, 2017)

Abbas Omar (University of Magdeburg, Germany) Overview on the Concepts of MIMO, Multiuser MIMO, and Massive MIMO (December 13, 2017)

Yoram Dagan (School of Physics and Astronomy, Tel Aviv University, Israel) On the superconducting and the insulating states of (111) SrTiO3/LaAlO3 interface (December 14, 2017)

Shruti Subramanian (Department of Materials Science & Engineering, The Pennsylvania State University USA) Tunable as-grown graphene contacts to semiconducting transition metal dichalcogenides (December 26, 2017)

Nasrin Banu (Department of Materials Science, IACS, Kolkata) High density nonmagnetic superconducting cobalt in thin film (December 28, 2017)

Srivasan Chakravarty (Department of Physics, University of Chicago, USA) Random access control, tunable coupling and enhanced lifetimes in superconducting circuits (January 2, 2018)

Somnath Bhattacharya (University of the Witwatersrand, South Africa) Odd-frequency Superconducting Order Parameter in Boron-doped Nanocrystalline Diamond Films (January 11, 2018)

Ashwin A. Seshia (Cambridge University, U.K.) Nonlinear resonances and phononic frequency combs in MEMS (January 12, 2018)

Shivani Sharma (Post-doctoral Fellow, I.I.T., Bombay) Structural phase transition and multiferroic studies in some transition metal oxides (January 16, 2018)

Subhamoy Ghatak (Physics Institute II, University of Cologne, Germany) Anomalous spin signal and Josephson supercurrent in bulk-insulating topological insulators (January 23, 2018)

Dinesh Kumar (Department of Physics, I.I.T. Madras, Chennai) Vibrational dynamics and superconducting properties of CVD grown boron doped diamond films (February 13, 2018)

Ganesh Adhikary (Post-doctoral Fellow, University of Nova Gorizia, Slovenia) Orbital-dependent electron dynamics in Fe-pnictide superconductors (Angle Resolved Photoelectron Spectroscopy (ARPES) and time- and angle-resolved Photoelectron spectroscopy (ARIES) study (March 6, 2018)

Infosys Condensed Matter Seminar

T Senthil (MIT) Symmetry Protected Topological Phases of Quantum Matter (July 4, 6, 2017)

Jason Petta (Department of Physics, Princeton University, USA) Generating light with single electrons (July 14, 2017)

Takis Kontos (Ecole Normale Superieure, Paris, France) Hybrid quantum circuits with carbon nanotubes (July 17, 2017)

Kater Murch (Washington University, USA) Measurement and control in superconducting qubits: from the quantum Zeno effect to quantum enhanced metrology (July 31, 2017)

Surajit Dhara (Department of Physics, University of Hyderabad, Hyderabad) Self-assembly of liquid crystal colloids via elasticity and topological defects (August 14, 2017)

Rajesh Ganapathy (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore) Deconstructing the Structural Glass Transition Through Experiments on Colloidal Suspensions (September 4, 2017)

Surjeet Singh (Indian Institute of Science Education and Research, Pune) Disordered Quantum Spin-1/2 Chains (September 18, 2017)

Krishnendu Sengupta (Indian Association for the Cultivation of Science, Kolkata) Translational symmetry broken Mott states of ultracold bosons (October 16, 2017)

Anindya Das (Indian Institute of Science, Bangalore) Andreev reflection in Graphene (October 23, 2017)


Arnab Das (Indian Association for the Cultivation of Science, Kolkata) Physics of Periodically Driven Closed Quantum Systems: Some Recent Elementary Developments (November 13, 2017)

Subir Sachdev (Department of Physics, Harvard University) Topological order in quantum matter (November 17, 2017)

Amit Ghosal (Department of Physical Science, Indian Institute of Science and Research, Kolkata) Signature of glassy behavior associated with melting of Coulomb clusters (December 11, 2017)

Yoram Dagan (School of Physics and Astronomy, Tel Aviv University, Israel) On the superconducting and the insulating states of (111) SrTiO3/LaAlO3 interface (December 14, 2017)

Sumathi Rao (Harish-Chandra Research Institute, Allahabad) Spin mode switching in the quantum Hall effect (December 18, 2017)

Shantanu Deb Nath (University of California, Berkeley, USA) Ultracold Atomic Physics, Computations on a Programmable Quantum Processor Based on Trapped Atomic Ions (December 19, 2017)

Sajal Dhara (Department of Physics, Indian Institute of Technology, Kharagpur) Light-matter interaction in two dimensional systems (December 27, 2017)

Philip Kim (Department of Physics, Harvard University) Electronic and Optoelectronic Physics in the van der Waals Heterojunctions of 2-dimensional Materials (January 9, 2018)

Aveek Bid (Department of Physics, Indian Institute of Science, Bangalore) Superconductivity in Oxide heterostructure (January 15, 2018)

Umesh Waghmare (Theoretical Science Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore) Functional Properties of Materials at Nano-scale:First-principles Theory (January 22, 2018)

Roderich Moessner (MPIPKS, Dresden, Germany), Magnetic Majorana Fermions (February 27, 2018)

Vishvesh Sudhir (LIGO Laboratory, MIT, USA) Quantum measurement and metrology with a mechanical oscillator (March 19, 2018)

Prerna Sharma (Indian Institute of Science, Bangalore) Curvature Instability of Chiral Colloidal Membranes on Crystallization (March 26, 2018)

Justin Song (Department of Physics, NTU, Singapore) Bloch-
Department of Theoretical Physics

Subhasish Mandal (Dept. of Applied Physics, Yale University) First principles investigation on Quantum Materials; (April 4, 2017)
Bindusar Sahoo (IISER,Trivandrum) Advances in N=4 conformal supergravity (April 10, 2017)
Zohar Komargodski (Simon Centre for Geometry and Physics) ’t Hooft Anomalies for Discrete Symmetries (April 17, 2017)
Sandipan Kundu (Cornell University) Causality Constraints in Quantum Field Theory (April 19, 2017)
Nilay Kundu (Kyoto University, Japan) AdS from optimization of path-integrals in CFTs (April 20, 2017)
Sandipan Kundu (Cornell University) Causality Constraints in Quantum Field Theory (April 21, 2017)
Shiroman Prakash (Dayalbagh Educational Institute, Agra) Some non-supersymmetric dualities in 2+1 dimensions (April 25, 2017)
Subhro Bhattacharjee (ICTS-TIFR, Bengaluru), Quantum spin liquids in XXZ Kagome antiferromagnets (April 26, 2017)
Marcello Musso (Max Planck Institute for Astrophysics, Garching) Excursion sets, peaks and multipole moments: connecting the large scale structure and the velocity field (April 28, 2017)
Prasad Hegde (Center for High Energy Physics, Indian Institute of Science, Bangalore) Studying QCD at finite density (May 4, 2017)
Manas Kulkarni (ICTS-TIFR, Bengaluru) Sub-diffusion and non-equilibrium probes of phases in incommensurate lattice models in low dimensions (May 18, 2017)
Sumilan Bannerjee (Indian Institute of Science, Bangalore) Solvable model for a dynamical quantum phase transition from fast to slow scrambling (May 26, 2017)
Sumit Das (University of Kentucky) A Three Dimensional View of the SYK Model (May 29, 2017)
Jyotirmoy Bhattacharya (Durham University) Surface transport properties of relativistic fluids (June 14, 2017)
Shiroman Prakash (Dayalbagh Educational Institute, Agra) 1/N and M/N Anomalous Dimensions in Chern-Simons with Matter (June 15, 2017)
Senthil Todadri (Department of Physics, MIT Boston, USA) Symmetry Protected Topological Phases of Quantum Matter (July 4, 2017)
Urna Basu (SISSA- International School for Advanced Studies, Italy) Frenetic aspects of nonlinear response: theory and experiment (July 7, 2017)
Diprimo Ghosh (Weizmann Institute of Science, Israel) Recent excitements in Flavour physics: Have we finally found New Physics at the LHC? (July 20, 2017)
Vipin Varma (City University of New York, USA) Anomalous transport in perturbed Heisenberg chain (August 10, 2017)
Chandrasekhar Bhamidipati (IIT, Bhuvnaneswar) Black Holes at Criticality (August 16, 2017)
Subhro Bhattacharjee (ICTS-TIFR, Bengaluru) Electric field response in a three dimensional U(1) Quantum spin liquid (August 17, 2017)
Sridhara Rao Dasu (University of Wisconsin, USA) Observation of the Higgs boson decay to a pair of τ leptons (August 17, 2017)
Sachin Jain (IISER, Pune) Small step towards computing all loop exact arbitrary m to n scattering amplitude in Chern-Simons matter theories (August 17, 2017)
Surbhi Khetrapal (IIIS, Bangalore) Local quenches and quantum chaos from higher spin perturbations (August 24, 2017)
Tarun Sharma (Wits University, Johannesburg, South Africa) Gauge and Gravitational anomalies of Discrete ZN symmetries (August 28, 2017)
Sunil Mukhi (IISER Pune) Universal Correlators from the Holomorphic Bootstrap (September 4, 2017)
Pravit Agarwal (Seoul National University, Korea) N=1 Lagrangians for generalized Argyres-Douglas theories (September 7, 2017)
Vivek Mishra (Oak Ridge National Laboratory) Origin of charge density wave order in the underdoped cuprates (September 13, 2017)
Bipasha Chakraborty (Jefferson Lab, USA) Low-energy hadronic physics using lattice QCD (September 20, 2017)
Ranjan Laha (Maim University, Germany) Ni’s from IceCube (September 21, 2017)
Justin David (Centre for High Energy Physics, Indian Institute of Science, Bangalore) Constraints on parity violating conformal field theories in d=3 (September 25, 2017)
Jorge Kurchan (Laboratoire de Physique Statistique, ENS-Paris) Sachdev Ye Kitaev model from the perspective of a glassman (September 29, 2017)
Satya Majumdar (LP TMS, Universite de Paris-Sud, France) Extremal statistics in the classical one dimensional Coulomb gas (October 4, 2017)
Shadab Alam (Royal Observatory, Edinburgh) Redshift, the treasure of modern cosmology (October 6, 2017)
Alok Laddha (CMI, Chennai) Asymptotic symmetries in QED and sub-leading soft photon theorem (October 9, 2017)
David Kaplan (Institute for Nuclear Theory, Seattle) From sign problems to a quantum computer (October 11, 2017)
David Kaplan (Institute for Nuclear Theory, Seattle) Chiral gauge theory on the lattice (October 12, 2017)
Peter Coles (Cardiff University) Wave mechanics and large scale structure of the Universe (October 13, 2017)
R. Loganayagam (ICTS-TIFR, Bangalore) Open EFT and Renormalisation (October 13, 2017)
Junggi Yoon (ICTS-TIFR, Bengaluru) SYK Models with Global Symmetry (October 16, 2017)
Tuhin Ghosh (NISER, Bhuvnaneswar) Measurements of Degree-scale B-mode polarization with BICEP2, Keck Array
and Planck (October 27, 2017)
P. Ramadevi (IIT, Bombay) Current status on polynomial invariants of knots: attempt towards classification (October 30, 2017)

Hridis Pal (Georgia Institute of Technology) Quantum oscillations without a Fermi surface (November 2, 2017)

Shiv Sethi (RRI, Bangalore) Cosmological observables and the nature of dark matter (November 3, 2017)

Aninda Sinha (IISc, CHEP) Strategies for bootstrap (November 6, 2017)

Shiv Sethi (RRI, Bangalore) Probing epoch of reionization (EoR) through redshifted HI line (November 7, 2017)

Karthik Inbasekar (Tel-Aviv University, Israel) Amplitudes and hidden symmetries in N=2 Chern-Simons matter theory (November 9, 2017)

George Stein (CITA, Toronto) Ultra-fast Cosmological Simulations with Peak Patch Method (November 10, 2017)

Arnab Kundu (SIINP, Kolkata) SYK chaotic and Global Charges (November 13, 2017)


Manabendra Nath Bera (ICFO, Barcelona) Universal Laws of Thermodynamics (November 21, 2017)

Bithika Jain (Korea Institute for Advanced Study, Seoul) On the Validity of the Effective Potential and the Precision of Higgs Self Couplings (November 23, 2017)

Djordje Radicevic (Perimeter Institute, Canada) Bosonization on a lattice in 2+1D (November 23, 2017)

Parijat Dey (Indian Institute of Science, Bangalore) Large spin bootstrap in Mellin space (November 27, 2017)

Jared Kaplan (John Hopkins University) Black Hole Thermodynamics and the Information Paradox in 2d CFT (November 28, 2017)

Raghu Mahajan (Princeton University, USA) A thermal Froissart-Gribov formula for CFTs (November 28, 2017)

Darshan Joshi (MPI Stuttgart) Topological quantum paramagnet in quantum spin systems (November 30, 2017)

Mukund Rangamani (University of California, Davis) Thermal equivalence and its applications (December 5, 2017)

Karunava Sil (IIT Roorkee) Applications of M-theory uplifted desingularized Conifold Geometries Relevant to Holographic Thermal QCD at Finite Coupling (December 6, 2017)

Srimoyee Sen (University of Washington, Seattle, USA) order parameters and color-flavor center symmetry in QCD (December 7, 2017)

Nishita Desai (University of Montpellier) Dark Matter searches with Colliders (December 7, 2017)

Shrenanda Ghosh (Technische Universitat, Dresden, Germany) Muon spin relaxation studies of SrRuO4 under uniaxial pressure (December 13, 2017)

Prahar Mitra ( Tata-Infosys Lecture Series) Asymptotic Symmetries and Soft Theorems in Quantum Field Theory (December 18, 2017)

Tumrol Neogi (IISER, Pune) N-extended Super BMS_3 algebras (December 28, 2017)

Subodh Patil (Niels Bohr Institute, Copenhagen) What’s left to learn from the CMB (from a phenomenological point of view)? (December 29, 2017)

Liju Philip (University of KwaZulu-Natal, Durban) Searching for cosmic dawn from the sub-Antarctic (January 2, 2018)

Rick Gupta (IPPP, Durham) Probing heavy new physics at the LHC using Effective Field Theory (January 11, 2018)

Siddharth Prabhu (Yale University, USA) A spin on gravitational radiation from the classical double copy (January 12, 2018)

Anjan Sen (Jamia Millia Islamia, Delhi) The price of shifting the Hubble constant and evidence (or no evidence) for dark energy evolution (January 12, 2018)

Shamik Banerjee (Institute of Physics, Bhubaneswar) Null-Infinity and Unitary Representation of Poincare group (January 15, 2018)

Ravi Kunjwal (Perimeter Institute, Canada) Witnessing nonclassicality from statistical proofs of the Kochen-Specker theorem (January 17, 2018)

Roji Pius (Perimeter Institute) On the Possibility of a Closed String Field Theory with Cubic Action (January 22, 2018)

Ayan Paul (DESY, Hamburg & Institut für Physik, Germany) Flavour Physics meets Heavy Higgs Searches (January 25, 2018)

Pinaki Chakraborty (Okinawa Institute of Science and Technology, Japan) The spectral link in turbulent frictional drag (January 29, 2018)

Priyanka Singh (IUCAA, Pune) The AGN-halo connection (February 2, 2018)

Pallab Basu (ICTS-TIFR, Bangalore) Complex Langevin dynamics and large-N gauge theories (February 5, 2018)

Subham Datta (Indian Institute of Science, Bangalore) Constraining spectral densities in conformal field theories (February 12, 2018)

Sergio Palomares Ruiz (Instituto de Fisica Corpuscular) Searches of New Physics with Neutrino Telescopes (February 16, 2018)

Madhusudhan Raman (IMSc, Chennai) Semiclassical Methods: A Jumble of Results and Directions (February 19, 2018)

Gunnar Bali (University of Regensburg) Distribution amplitudes from Euclidean correlation functions (February 22, 2018)


Pasquale D. Serpico (LAPTh Annecy) Indirect dark matter: challenges and opportunities (February 23, 2018)

Lakshya Bhardwaj (Perimeter Institute) Classification of 6d SCFTs and supersymmetric little string theories (February 26, 2018)

Francesco Capozzi (MPP, Munich) DUNE as the Next-Generation Solar Neutrino Experiment; February 26, 2018.

Sujay Ashok (IMSc, Chennai) Surface operators in supersymmetric gauge theories (March 5, 2018)

Arpan Saha, Quantum corrections to the universal hypermultiplet metric (March 8, 2018)

Venkitesh Ayyar (University of Colorado, Boulder, USA) Study of SU(4) Composite Higgs Model with fermions in multiple representations (March 15, 2018)

Vikas Krishnamurthy (Ernst Schrödinger Institute, Vienna) Theory and applications of analytic functions on multiply connected domains (March 15, 2018)

Chethan Krishnan (Centre for High Energy Physics, Indian Institute of Science, Bangalore) A Neumann Boundary for Gravity (March 19, 2018)


Nihar Saboo (Texas A & M University) Recent jet physics in Heavy-Ion collisions at RHIC (March 27, 2018)

Kabir Ramola (Brandeis University, USA) Soft Disk Packings: Unjamming and Stress Localization (March 28, 2018)
TIFR Centres

International Centre for Theoretical Sciences, Bengaluru

Manjunath Krishnapur (Indian Institute of Science, Bangalore) Nodal Sets of Eigenfunctions of Laplacian, with Randomness (28 March 2018)
Joseph Samuel (Raman Research Institute, Bangalore) Gravity and Decoherence (26 March 2018)
Suchetana Chatterjee (Presidency University, Kolkata) Subtractive Supermassive Black Holes and their Host Dark Matter Halos (22 March 2018)
Sushil Mujumdar (Tata Institute of Fundamental Research, Mumbai) Anderson Localization Studies in Periodic-on-Average Random Systems (22 March 2018)
Debasish Chaudhuri (Institute of Physics, Bhubaneswar) Confinement Shapes and Positions Bacterial Chromosome (21 March 2018)
L. Resmi (Indian Institute of Space Science and Technology, Kerala) GRB170817:a: A Burst that Challenged Perceptions (21 March 2018)
Subhajit Goswami (Institut des Hautes Études Scientifiques, France) The Truncated Correlations of the Ising Model in any Dimension Decay Exponentially Fast at all but the Critical Temperature (21 March 2018)
Prateek Sharma (Indian Institute of Science, Bangalore) Angular Momentum Transport in Accretion Flows (19 March 2018)
Ajit Kumar Mehta (ICTS-TIFR, Bangalore) Accurate Spiral-Merger-Kinglowl Gravitational Waves for Non-Spinning Black Hole Binaries including the Effect of Subdominant Modes (16 March 2018)
Kabir Ramola (Brandeis University, U.S.A) Statistical Mechanics of Granular Solids and Dense Suspensions (13 March 2018)
Chiranjib Bhattacharyya (Indian Institute of Science, Bangalore) Parsmiorus Model Estimation in the Presence of Correlated Variables (12 March 2018)
Maulik Parikh (Arizona State University, U.S.A) Generic Local Properties of Spacetime (8 March 2018)
Guillaume Faye (Institut d'astrophysique de Paris, France) Modelling binary systems of compact objects: the fourth-order post-Newtonian dynamics (6 March 2018)
Aparajita Dasgupta (Imperial College, London) Expansion of Ultradifferentiable Functions and Ultradistributions (6 March 2018)
Vikas Krishnamurthy (Erwin Schrodinger Institute, Vienna) Applications of conformal mapping from multiply connected domains to selected fluid systems (5 March 2018)
Vanamala Viswanatha (Azim Premji University, Bangalore) The Life of Harishchandra: A Story in Song (26 February 2018)
Kasi Jaswin (ICTS-TIFR, Bangalore) Matrix Models and Complex Langevin Dynamics (23 February 2018)
Varun Gulshan (Google, Bengaluru) Machine Learning in Imaging and More! (22 February 2018)
L S Shashidhara (Indian Institute of Science Education and Research, Pune) Evolution of Human Cognition (19 February 2018)
Vikas Krishnamurthy (Erwin Schrodinger Institute, Vienna) Theory and Applications of Analytic Functions on Multiply Connected Domains (16 February 2018)
Sourav Chakraborty (Chennai Mathematical Institute, Chennai) Dealing with One Aspect of Big Data (15 February 2018)
Vivek Chaurasia (University of Jena, Germany) Neutron Stars in Numerical Relativity: Updates from the Jena Group (15 February 2018)
Jose Matthew (Indian Institute of Science Education and Research, Thrissur) Particle Physics Models of Inflation in Modified Gravity (13 February 2018)
Suvrat Raju (ICTS-TIFR, Bangalore) The Black Hole Interior and Holography (12 February 2018)
Adway Mitra (ICTS-TIFR, Bangalore) The Indian Monsoon through the lens of a Discrete Random Field (9 February 2018)
Svante Linusson (KTH Stockholm, Sweden) Some TASEP-models on a ring (7 February 2018)
Roji Pius (Perimeter Institute for Theoretical Physics, Canada) The Geometry of Closed String Theory (6 February 2018)
Krishnendu Sengupta (Indian Association for the Cultivation of Science, Kolkata) Translational symmetry broken Mott states of ultracold bosons (5 February 2018)
Shubha Tole (Tata Institute of Fundamental Research, Mumbai) Constructing a brain: structures and circuits (29 January 2018)
Pranav Pandit (University of Vienna, Austria) Spectral networks, symplectic geometry, and WKB analysis (29 January 2018)
Pranav Pandit (University of Vienna, Austria) From Homotopical Mathematics to Emergent Geometry (24 January 2018)
Yogeshwar Prasad (Harish-Chandra Research Institute, Allahabad) Study of fermionic superfluid state in ‘clean’ and ‘dirty’ bilayer optical lattice systems circumventing the ‘cooling problem,’ (19 January 2018)
Turmoli Neogi (Indian Institutes of Science Education and Research, Pune) N-extended Super BMS$_3$ algebras (19 January 2018)
Eitan Tadmor (University of Maryland, U.S.A) Emergent behavior in self-organized dynamics: from consensus to hydrodynamic flocking (18 January 2018)
Mukul Bhattacharya (University of Texas at Austin, U.S.A) Bound orbits around Schwarzschild Black Holes in pure Lovelock gravity (2 January 2018)
Takehiro Azuma (Setsuman University, Japan) Complex Langevin analysis of the spontaneous symmetry breaking in dimensionally reduced super Yang-Mills models (1 January 2018)
Vikas Krishnamurthy (Federal University of Pernambuco, Brazil) New frontiers in applied complex analysis: compressible flows and vortex dynamics (29 December 2017)
Sougata Dhar (Northern Illinois University, U.S.A) Linear, half linear and fractional Lyapunov-type inequalities and applications (27 December 2017)
Supratik Sarkar (Indian Institute of Science Education and Research, Pune) Trans-Plantckian Issues and Emergent Gravity: From Bose- Einstein Condensates (BEC) to Analog Black Holes (21 December 2017)
Manoj Kumar (Jawaharlal Nehru University, New Delhi) Random Field Ising Model in the Absence and Presence of a Uniform Magnetic Field: Ground States, Scaling Properties and Non-Porod Behavior (20 December 2017)

Roji Pius (Perimeter Institute for Theoretical Physics, Canada) On the Possibility of a Cubic Closed String Field Theory (20 December 2017)

Kingshuk Sarkar (Indian Institute of Science, Bangalore) Studies of Diamagnetism and Thermoelectric Transport in High Temperature Superconductors and Graphene (20 December 2017)

Sumanta Chakraborty (Indian Association for the Cultivation of Science, Kolkata) Action Principle for Gravity, Null Surfaces and Thermodynamics (19 December 2017)

Ruchi Saxena (Harish-Chandra Research Institute, Allahabad) Emergent topological phases in periodically driven SO-coupled materials and their exotic bulk-edge correspondence (19 December 2017)

Michael Zlotnikov (Brown University, USA) Scattering Equations and Soft Theorems (19 December 2017)

Srivatsan Chakram (University of Chicago, USA) Random Access Quantum Information Processing Using Multimode Circuit Quantum Electrodynamics (18 December 2017)

Alexandra Miller (University of California, Santa Barbara, USA) Measuring Topology in Quantum Gravity (18 December 2017)


Kiran Sridhara Kedlaya (University of California, San Diego) The ABC conjecture (18 December 2017)

Aparajit Ganguly (Rhodes University, South Africa) Numerical relativity and modified gravity (15 December 2017)

Vivek Mishra (Oak Ridge National Laboratory, USA) Pairing in Cuprates: Signatures of a Non-BCS Paradigm (15 December 2017)

Mukund Rangamani (University of California, Davis, USA) Thermal Equivariance and its Applications (14 December 2017)

Girish Sharma (Virginia Polytechnic Institute & State University, USA) Beyond Graphene – Novel Topological Phenomena in Weyl Semimetals and some 2D Semiconductors (14 December 2017)

Saurish Chakrabartty (ICTS-TIFR, Bangalore) Light-Cone Spreading of Perturbations and the Butterfly Effect in a Classical Heisenberg Chain and Block Analysis to Calculate Length-scales in super-cooled liquids (13 December 2017)

G.S. Agarwal (Texas A & M University, USA) Subradiance to Hyperradiance in Strong Coupling Cavity QED (13 December 2017)

Abhishek Agarwal (American Physical Society, USA) Entropy of Entangled Gauge Fields in D = 2+1 (12 December 2017)

N S Manton (University of Cambridge, UK) Some Characteristic of Topological Science (12 December 2017)

Abhishek Prakash (Stanford University, USA) Eigenstate Phases of a Disordered Spin Chain with Finite Non-Abelian Symmetry (12 December 2017)

Abhishek Agarwal (American Physical Society, USA) Everything You Wanted to Know About Physical Review Letters But Were Afraid to Ask (11 December 2017)

NS Manton (University of Cambridge, UK) Skyrmions, Nuclei and SU (4) Weight Clusters (11 December 2017)

Subir Sachdev (Harvard University, USA) From the SYK Model to a Theory of the Strange Metal (8 December 2017)

Jared Kaplan (Johns Hopkins University, USA) Black Hole Thermodynamics and the Information Paradox in 2d CFT (5, 6, 7 December 2017)


Sarosh N. Fatakia (TIFR, Mumbai) Unity amidst Diversity in the Eukaryotic Nucleus (30 November 2017)


Roderich Moessner (Max Planck Institute for the Physics of Complex Systems, Germany) Thermodynamics and Order Beyond Equilibrium – From Floquet Thermalisation to Time Crystals (27 November 2017)

Adhip Agarwala (ICTS-TIFR, Bangalore) Seeking Topological Phases in Amorphous Systems and in Fractals (24 November 2017)

Mohit Kumar Jolly (Rice University, USA) Computational Systems Biology of Cancer Metastasis: Can Theory Help Understand Cancer Biology? (22 November 2017)

Karthik Inbasekar (Tel Aviv University, Israel) Amplitudes and Hidden Symmetries in N=2 Chern-Simons Matter Theory (22 November 2017)

Nishita Desai (University of Montpellier, France) Dark Matter Searches at the LHC and Beyond (21 November 2017)

Karunava Sil (Indian Institute of Technology Roorkee) Applications of M-theory Uplifted Desingularized Conifold Geometries Relevant to Holographic Thermal QCD at Finite Coupling (21 November 2017)

Debjit Goswami (ICTS-TIFR, Bangalore) Active Torque Generation in a Disordered Actomyosin Network (21 November 2017)

Vijaykumar Krishnamurthy (ICTS-TIFR, Bangalore) Morphogenetic Patterns: Biochemical Signalling, Mechanics and Geometry (20 November 2017)


Tirthankar Roy Choudhury (NCR-4, Pune) Cosmic Neutral Hydrogen as a Probe of the First Stars in the Universe (13 November 2017)

Parijat Dey (Indian Institute of Science, Bangalore) Large Spin Bootstrap in Mellin Space Speaker (8 November 2017)

Allan Peter Young (University of California, Santa Cruz, USA) Critical Phenomena and Griffiths-McCoy Singularities in Quantum Spin Glasses (7 November 2017)

Vidita Vaidya (Tata Institute of Fundamental Research, Mumbai) Neuroplasticity – A Lifelong Dialogue between your Brain and the Environment (6 November 2017)

Manabendra Nath Ber (ICTS – The Institute of Photonic Sciences, Spain) Universal Laws of Thermodynamics (3 November 2017)


Sameer Murthy (King’s College London, UK) Equivariant Bst Cohomology & Localization in Supergravity (25 October 2017)

Sushil Mujumdar (Tata Institute of Fundamental Research, Mumbai) Anderson Localization and Levy Sums in Random Lasers (23 October 2017)
Sanjay Watergaonkar (Tata Institute of Fundamental Research, Mumbai) Strength of Weak (Non-Covalent) Interactions (16 October 2017)
Pierre le Doussal (Ecole Normale Superieure, France) Memory Effects in Kardar Parisi Zhang Growth: Exact Results via the Replica Bethe Ansatz (12 October 2017)
Bernard Deconinck (University of Washington, USA) Lectures on the Unified Transform Method for Linear Partial Differential Equations (11 October 2017)
Anirban Basak (Weizmann Institute of Science, Israel) Local Weak Limit of Ferromagnetic Ising Measure on Locally Tree-Like Graphs (11 October 2017)
Amitabh Joshi (ICTS, Bangalore) Experimental Ecology and Evolution in the Laboratory (9 October 2017)
Shamik Banerjee (Institute of Physics, Bhubaneswar) Celestial Sphere and Unitary Representation of the Poincare Group (27 September 2017)
K. Sandeep (TIFR Centre for Applicable Mathematics, Bangalore) Sharp Sobolev Embeddings and Related Problems (25 September 2017)
Bipasha Chakraborty (Jefferson Lab, USA) Calculation of Hadronic Vacuum Polarisation Contribution to Muon G-2 from Lattice QCD (22 September 2017)
Rupamani J Majumdar (Leiden University Medical Center, Netherlands) Spatiotemporal Organization of Action Potential Duration Alternans in Arrhythmogenesis (22 September 2017)
Krishna Venkateswaru (University of Washington, USA) Exploring the Gravitational Universe with LIGO And Torsion-Balance Experiments (21 September 2017)
Debarghya Banerjee (Institute for Theoretical Physics, Leiden University) Odd Viscosity in Chiral Active Fluids (21 September 2017)
Prafulla Agarwal (Seoul National University, South Korea) N=1 Lagrangians for Generalized Argyres-Douglas Theories (19-20 September 2017)
Kinjal Dasbiswas (University of Chicago, USA) Symmetry Breaking in Cells: Physical Forces and Flows (13 September 2017)
Biman B. Nath (Ramakrishna Research Institute, Bangalore) Blowing in the Galactic Wind Speaker (11 September 2017)
Kinjal Dasbiswas (University of Chicago, USA) Soft Matter Physics with Cells and Tissue (8 September 2017)
Rahul Kashyap (ICTS-TIFR, Bangalore) How to Explode White Dwarf? (8 September 2017)
Onuttom Narayan (University of California, Santa Cruz, USA) Glassy Dynamics in Disordered Oscillator Chains (6 September 2017)
Ranjan Laha (KIPAC, Stanford University, USA) Status of Dark Matter Indirect Detection (5 September 2017)
Sanjeeb Surej (Tata Institute of Fundamental Research, Mumbai) Portfolio Credit Risk: Simple Closed form Approximate Maximum Likelihood Estimator and Related Issues (4 September 2017)
Alexander Mietke (Max Planck Institute for the Physics of Complex Systems, Dresden, Germany) Self-organised dynamics of curved and deforming active surfaces (29 August 2017)
Probab Chaudhuri (Indian Statistical Institute, Kolkata) Shape of the Earth, Motion of the Planets and the Method of Least Squares (28 August 2017)
Daniel Grumiller (TU Wien, Austria) Gravity in lower dimensions (21-23 August 2017)
Arjun Bagchi (Indian Institute of Technology Kanpur) Constructing the BMS Bootstrap (22 August 2017)
Rukmini Dey (ICTS-TIFR) Some aspects of minimal surfaces, maximal surfaces and solitons (21 August 2017)
Sanchayan Sen (McGill University, Quebec) Percolation, spatial minimal spanning trees, and Stein’s method (17 August 2017)
Sanchayan Sen (McGill University, Quebec) Geometry of structures constructed on random regular graphs (16 August 2017)
Rama Govindarajan (ICTS-TIFR) What do stratification and rotation do to shear and vortical flows (14 August 2017)
Adhip Agarwala (ICTS-TIFR) Seeking Topological Phases in Amorphous Systems and in Fractals (11 August 2017)
Florian Sprung (Institut für Advanced Study, Princeton) On The Birch and Swinnerton-Dyer Conjecture (10 August 2017)
Zoltan Heiman (Columbia University, USA) Merging Supermassive Black Hole Binaries (10 August 2017)
Umesh Vijayashanker (University of the Witwatersrand, Johannesburg) Supersymmetric Chern-Simons-matter theories and BCFW recursion (9 August 2017)
Bikas K. Chakrabarti (Saha Institute of Nuclear Physics, Kolkata) Quantum Tunnelling & Ergodicity in Quantum Spin Glasses (8 August 2017)
Mayukh Mukherjee (Technion – Israel Institute of Technology, Israel) Asymptotic estimates on the geometry of Laplace eigenfunctions (7 August 2017)
Bikas K. Chakrabarti (Saha Institute of Nuclear Physics, Kolkata) Econophysics of Income & Wealth Inequalities (7 August 2017)
Priti Dalai (Indian Institute of Technology Madras, Chennai) Nonequilibrium quantum transport: depletion and mobility induced clustering (4 August 2017)
Jason R. Picardo (ICTS-TIFR, Bangalore) Pattern selection at unstable fluid interfaces (4 August 2017)
Bappaditya Roy (Indian Institute of Technology Guwahati, Assam) Discontinuous percolation transition: A search for new models and scaling theory (3 August 2017)
Suchetana Sadhukhan (Indian Institute of Technology Kharagpur, West Bengal) Statistical analysis of complex systems with dynamical constraints: a random matrix approach (3 August 2017)
Aditya Gilra (École Polytechnique Fédérale de Lausanne, Switzerland) A learning scheme for neural networks in the brain to predict and control body movement (3 August 2017)
Sayani Chatterjee (S. N. Bose National Centre for Basic Sciences, Kolkata) Additivity and mass fluctuations in conserved-mass transport processes (3 August 2017)
Arghya Das (S. N. Bose National Centre for Basic Sciences, Kolkata), Exact static and dynamic characterization of conserved-mass transport processes (3 August 2017)

Vimal Simha (Centre for Extragalactic Theory, University of Western Cape, South Africa), Cosmology in the low redshift universe (2 August 2017)

Sankaran Nampoothiri (Indian Institute of Science Education and Research Thiruvananthapuram, Kerala), Role of curvature and thickness in reaction-diffusion systems (1 August 2017)

Prasad V V (Institute of Mathematical Sciences, Chennai), Velocity statistics of Granular gases (26 July 2017)

Rahul Danekekar (International Centre for Theoretical Physics, Trieste), A hierarchical lattice model for the H-bond network in water (26 July 2017)

Arnab Priya Saha (Institute of Mathematical Sciences, Chennai), Double Soft Limit of Graviton Amplitude from CHY formalism (25 July 2017)


Avani Vikrambhai Patel (Indian Institute of Science Education and Research, Bhopal), The Late-time Cosmology of f(R) Theory of Modified Gravity (24 July 2017)

Yamuna Swamy (Indian Institute of Science, Bangalore), Studies on Kernel Based Edge Detection and Hyper Parameter Selection in Image Restoration and Diffuse Optical Image Reconstruction (24 July 2017)

Diptimoy Ghosh (Weizmann Institute of Science, Israel), Symmetries and Hierarchies of the Standard Model (21 July 2017)


Sharad Ramanathan (Harvard University, USA) Reading the mind of cells as they make developmental decisions (20 July 2017)

Saibal Ganguli (Harish-Chandra Research Institute, Allahabad), Geometric Quantization of Toda Systems and a short survey of other works (14 July 2017)

Sumathi Rao (Harish-Chandra Research Institute, Allahabad), Spin mode switching in the quantum Hall effect (12 July 2017)

Shivakumar Jolad (Indian Institute of Technology, Gandhinagar), Shrinking government schools: Small schools and convection in the ocean circulation (26 June 2017)

Ganesh Ramachandran (Institute of Mathematical Sciences, Chennai), Vortex core order and field-induced supersolidity (23 June 2017)

Priyanka Maiti (ICTS-TIFR, Bangalore) Patterns near the onset of convection in rotating Rayleigh-Bénard systems (23 June 2017)

Trilochan Sastry (Indian Institute of Management, Bangalore), The Academic as an Agent of Social Change (19 June 2017)

Deepak Bhat (ICTS-TIFR, Bangalore) Dynamics of a piston pushed by a single particle gas: A microscopic model for Szilard engine (15 June 2017)

Anurag Kumar Singh (University of Utah, USA), The number of equations defining an algebraic set (14 June 2017)

Sambuddha Sanjay (ICTS-TIFR, Bangalore) Some recent advances in quantum spin-ice systems and non-equilibrium transport in 1D (12 June 2017)

Archak Purkayastha (ICTS-TIFR, Bangalore) Quantum thermal diode with low non-linearity and/or at high temperature (9 June 2017)

Jemseena V (ICTS-TIFR, Bangalore) Pattern formation in active matter (9 June 2017)

Hrishik Kedia (University of Chicago, USA) On the Construction and Dynamics of Knotted Fields (8 June 2017)

Sanchayan Sen (McGill University, Québec) Random structures: Phase transitions, scaling limits, and universality (6 June 2017)

Abhirup Ghosh (ICTS-TIFR) Detection of a third binary black hole coalescence by Advanced LIGO (2 June 2017)

Savan Khare (Yale University, USA) Progress in calculating current correlators in Ads/CFT (2 June 2017)

Shiroman Prakash (Dayalbagh University, Agra), Solving theories with a slightly broken higher spin symmetry (30 May 2017)

Mukund Thattai (NCBS-TIFR, Bangalore) Possible and Impossible Cells (29 May 2017)

Sumit R. Das (University of Kentucky, USA) A Three Dimensional View of the SYK Model (26 May 2017)

Jemseena V (ICTS-TIFR, Bangalore) Causes and Consequences of Aging in Microtubule Catastrophe (26 May 2017)

Pranjal Nayak (Tata Institute of Fundamental Research, Mumbai), Virasoro Coadjoint Orbits of Syk/Tensor-Models & Emergent 2-D Quantum Gravity (25 May 2017)

Bulbul Chakraborty (Brandeis University, USA) The Hidden World of Sand (24 May 2017)

Harsha Hutridurga (Imperial College London, UK) Weak Convergence Approaches in Homogenisation Theory, Old and new (22 May 2017)

Harsha Hutridurga (Imperial College London, UK) Cloaking Strategies for Transient Heat and Mass Transfer (23 May 2017)

Vijit Maithel (Indian Institute of Science, Bangalore) Dynamics in Simple Monsoon Models (18 May 2017)

Vijit Maithel (Indian Institute of Science, Bangalore) QTCM – Model and Concepts (16 May 2017)

Paritosh Pandya (Tata Institute of Fundamental Research, Mumbai), Mathematics of Program Construction (15 May 2017)

Suman Acharyya (ICTS-TIFR, Bangalore) State Estimation using the Gradient Descent Method (12 May 2017)

Prabuddha Chakraborty (Indian Statistical Institute Chennai Centre), Presence of Quantum Diffusion in Two Dimensions: Is there a Metallic State in Two Dimensions in the Presence of Disorder? (9 May 2017)

Subroto Mukerjee (Indian Institute of Science, Bangalore), Ergodicity and Localization in Many-Body Systems with
Mobility Edges (9 May 2017)  
Arun Paramekanti (University of Toronto, Canada) Emergent Phenomena in Correlated Quantum Materials (8 May 2017)  
Nilay Kundu (Kyoto University, Japan) Towards a Second Law for Lovelock Theories (4 May 2017)  
Sourav Gupta (Tata Institute of Fundamental Research, Mumbai) Effective Theories for Thermal QCD (3 May 2017)  
Arnab Rai Choudhuri (Indian Institute of Science, Bangalore) The Mysterious Magnetic Personality of our Sun (1 May 2017)  
Harsha Hutridurga (Imperial College London, UK) A new approach to study strong advection problems in turbulent diffusion theory (11 April 2017)  
Mustansir Barma (TIFR Centre for Interdisciplinary Sciences, Hyderabad) Ordered Phases in Coupled Nonequilibrium Systems (10 April 2017)  
Carmen Molina-Paris (University of Leeds, United Kingdom) Mathematical Immunology: An introduction (4 April 2017)  
Govindasamy Bala (Indian Institute of Science, Bangalore) ‘When and how will the “anthropogenic CO2” be removed by natural processes?’ (3 April 2017)  

Infosys-ICTS Chandrasekhar Lectures  
Sign Problems and Quantum Computers  
David B. Kaplan (University of Washington, USA) ICTS-TIFR, Bangalore, 31 January-3 February 2018  
S. Chandrasekhar’s Fluid Dynamics  
Katepalli Raja Sreenivasan (NYU Tandon School of Engineering & Courant Institute of Mathematical Sciences) ICTS-TIFR, Bangalore, 22-24 January 2018  
Dynamics of 2+1-dimensional Quantum Field Theory  
Nathan Seiberg (Institute for Advanced Study, Princeton, USA) ICTS-TIFR, Bangalore, 8-12 January 2018  
Fluctuations and Large Deviations in Nonequilibrium Systems  
Bernard Derrida (Laboratoire de Physique Statistique, Ecole Normale Supérieure, France) ICTS-TIFR, Bangalore, 22-24 August 2017  
Microscopic Stochastic Heat Engines Using Nonequilibrium Bacterial Reservoirs  
Ajay Sood (Indian Institute of Science, Bangalore) ICTS-TIFR, Bangalore, 7-9 August 2017  
Models of Cosmological Inflation  
John Ellis (King’s College, London) ICTS-TIFR, Bangalore 5-7 June 2017  

Infosys-ICTS Turing Lectures  
Daniel S. Fisher (Stanford University, USA) Evolutionary Dynamics and Diversity in Large Populations (ICTS-TIFR, Bangalore, 8 March 2018)  
Paul B. Rainey (Department of Microbial Population Biology, Max Planck Institute for Evolutionary Biology, Plön, Germany; Laboratoire de Génétique de l’Evolution, ESPCI Paris, France & The New Zealand Institute for Advanced Study, Massey University, Auckland, New Zealand) The Evolution of Individuality and Why Life is Hierarchically Structured (ICTS-TIFR, Bangalore, 15 December 2017)  

Distinguished Lectures  
Hirosi Ooguri (Frederick Kavli Professor of Theoretical Physics and Mathematics, Director of the Walter Burke Institute for Theoretical Physics, Caltech; Principal Investigator, Kavli IPMU, The University of Tokyo and President, Aspen Center for Physics) Symmetry in Quantum Gravity (ICTS-TIFR, Bangalore, 15 January 2018)  
David Gross (KITP-University of California, Santa Barbara) The SYK Model (Kavli Distinguished Lecture), ICTS-TIFR, Bangalore, 8 January 2018  
Philip Candelas FRs (Rouse-Ball Professor of Mathematics, Mathematical Institute, Univ. of Oxford, UK) Geometry and Arithmetic of Calabi-Yau Manifolds (ICTS-TIFR, Bangalore, 7 April 2017)  

Public Lectures  
Daniel Fisher (Stanford University) ‘Can Evolution be Understood Quantitatively?’ (ICTS-TIFR, Bangalore, 6 March 2018)  
Hirosi Ooguri (Fred Kavli Professor of Theoretical Physics and Mathematics, Director of the Walter Burke Institute for Theoretical Physics, Caltech; Principal Investigator, Kavli IPMU, The University of Tokyo and President, Aspen Center for Physics) The Science of the Man from the 9 Dimensions (J. N. Planckian, Bangalore, 14 January 2018)  
Robbert Dijkgraaf (IAS, Princeton) ‘The Usefulness of Useless Knowledge’ (Christ University, Bangalore, 7 January 2018)  
Joachim Frank (Columbia University, New York) Deciphering the workings of molecules, building blocks of life, with the electron microscope (ICTS-TIFR, Bangalore, 1 Nov 2017)  
John Ellis (King’s College, London) ‘What are we? Where do we come from? Where are we going?’ (ICTS-TIFR, Bangalore, 8 June 2017)  

Einstein Lectures  
Rana Adhikari (Professor of Physics, Caltech) ‘In Brightest Day and Blackest Night’ (BMS College of Engineering, Bangalore, 20 February 2018)  
Manas Kulkarni (ICTS-TIFR, Bangalore) Engineering Exotic States of Light and Matter (M S Ramaiah Institute of Technology, Bangalore, 8 September 2017)  
Rama Govindarajan (ICTS-TIFR, Bangalore) ‘The Life History of a Raindrop’ (School of Sciences, Jain University, Bangalore, 29 July 2017)  
Suvrat Raju (ICTS-TIFR, Bangalore) ‘Black Holes and the Reversibility of Time’ (National College, Bangalore, 12 April 2017)  

Vishveshwara Lectures  
Kip S. Thorne (Feynman Professor of Theoretical Physics at Caltech
& 2017 Nobel Laureate in Physics) Exploring the Universe with Gravitational Waves: From the Big Bang to Black Holes (ICTS-TIFR, Bangalore, 11 January 2018)

Kapi with Kuriosity

Shannon Olsson (NCBS-TIFR, Bangalore) Endless Forms Most Beautiful (J. N. Planetarium, Bangalore, 25 March 2018)

Urbasi Sinha (Quantum Information and Computing (QiC) laboratory at Raman Research Institute, Bangalore) Fascinating World of Photons, Superposition and Entanglement (J. N. Planetarium, Bangalore, 25 February 2018)

Ramesh Narayan (Thomas Dudley Cabot Professor of the Natural Sciences at Harvard University and Senior Astronomer at the Smithsonian Astrophysical Observatory) Black Holes (J. N. Planetarium, Bangalore, 21 January 2018)

Harmit Malik (Fred Hutchinson Cancer Research Center, Seattle) Paleovirology: The Modern Legacy of Ancient Viruses (J. N. Planetarium, Bangalore, 10 December 2017)

Mahan Mj (Tata Institute of Fundamental Research, Mumbai) Shapes and Geometry of Surfaces (J. N. Planetarium, Bangalore, 26 November 2017)

Roddam Narasimha (Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore) Great Triumphs and False Stories: A Brief History of Histories of Indic and European Science through the Ages (J. N. Planetarium, Bangalore, 8 Oct 2017)

Hugo Touchette (National Institute for Theoretical Physics, Stellenbosch) How Connected Are You? An Introduction to Graph Theory and Network Science (Jawaharlal Nehru Planetarium, Bangalore, 17 September 2017)

Julia Mary Yeomans (St Hilda’s College, University of Oxford) Fluids Everywhere: Flows on All Scales (Jawaharlal Nehru Planetarium, Bangalore, 6 August 2017)

Kater Murch (Washington University, St. Louis) The Arrow of Time in Quantum Measurement (Jawaharlal Nehru Planetarium, Bangalore, 23 July 2017)

S. Seetha (Programme Director at Space Science Program Office, ISRO (HQ)) ASTROSAT: A Multiwavelength View of the Universe (Christ University, Bangalore, 11 June 2017)

Bard Ermentrout (University of Pittsburgh, U.S.A) The Visions of Shamans and Saints: Dynamic instabilities in Neuroscience (Jawaharlal Nehru Planetarium, Bangalore, 14 May 2017)

Speaker: Mustansir Barma (TIFR Centre for Interdisciplinary Sciences, Hyderabad) Title: Random Walks in Science (St. Joseph’s College, Bangalore, 9 April 2017)

National Centre for Radio Astrophysics, Pune

Anupreeta More (Kavli IPMU, Japan) Probing the dark side of the Universe with strong gravitational lensing (April 3, 2017)


Samir Choudhuri (NCR-A-TIFR) Visbility-based power spectrum estimation for low-frequency radio interferometric observations (April 24, 2017)

Eric Hooper (University of Wisconsin-Madison & WYIN Observatory, U.S.A) A 3-D view into the Connection and History of Galaxies and Active Galactic Nuclei (June 5, 2017)

Pawan Kumar (University of Texas-Austin, U.S.A) Exploring the Progenitors of long-duration Gamma Ray Bursts (July 5, 2017)

Jonathan Granot (The Open University of Israel, Israel) Experimental Bounds on Quantum Gravity from Fermi Observations of GRBs (July 10, 2017)

Anish Roshi (National Radio Astronomy Observatory, U.S.A) Highly Sensitive Cryogenic Phased Array Feed (July 14, 2017)

Manjari Bagchi (Institute of Mathematical Sciences, Chennai) Binary radio pulsars with compact companions to understand basic physics (July 28, 2017)

K. P. Singh (TIFR-Mumbai) X-ray Spectroscopy in Astronomy (July 31, 2017)


Paula Benaglia (Argentine Institute of Radio Astronomy, Argentina) Massive stars with the GMRT (August 21, 2017)

Uma Ramakrishnan (National Centre for Biological Sciences, Bengaluru) Are genomic data relevant for conservation? (September 4, 2017)

Huib Intema (University of Leiden, The Netherlands) From black belt to novice: Enabling astrophysics with the GMRT (September 11, 2017)

Kajari Mazumdar (TIFR-Mumbai) The Large Hadron Collider, LHC project (September 18, 2017)


Satish Sonkamble (NCR-A-TIFR, Pune) AGN Feedback in Galaxy Clusters (September 29, 2017)

Amitava Raychaudhuri (University of Calcutta, Kolkata) Balancing the left with the right: The road to unity (October 3, 2017)

Carlos Wuenschke (National Institute for Space Research, Brazil) The BINGO radio telescope and the 21 cm Cosmology (October 6, 2017)


Shiraz Minwalla (TIFR, Mumbai) Hydrodynamics and Membrane Dynamics from Gravity (October 20, 2017)

Michael Nowak (MIT Kavli Institute for Astrophysics and Space Research, U.S.A) Are Black Holes as simple as they used to be? (October 23, 2017)


Sourabh Paul (NCR-A-TIFR, Pune) Towards the measurement of 21cm HI power spectrum from the Epoch of Reionization (October 30, 2017)

K. G. Arun (Chennai Mathematical Institute, Chennai) Tale of a binary neutron star merger (November 13, 2017)

Vishal Gaijar (University of California, Berkeley, U.S.A) A new insight into the origin of repeating fast radio bursts (November 24, 2017)

Debades Bandyopadhyay (Saha Institute of Nuclear Physics, Kolkata) Neutron Star Equation of State and Maximum
Mass: Lessons from GW170817 (December 4, 2017)

Aritra Basu (Bielefeld University, Germany) Magnetic Fields in High-Redshift Galaxies (December 15, 2017)

Frank Shu (University of California, Berkeley and San Diego, USA; National Tsing Hua University, China) Formation of Sunlike Stars and Planetary Systems (December 18, 2017)

Andy Fabian (Institute of Astronomy, Cambridge, UK) AGN Feedback (December 20, 2017)

Nipanjana Patra (University of California, Berkeley, USA) Precision measurement challenges of 21cm Cosmology (February 2, 2018)

Viswesh R. Marthi (Canadian Institute of Theoretical Astrophysics, Canada) Imaging with Interstellar Baselines (February 23, 2018)

Ruta Kale (NCRA-TIFR, Pune) Cosmic Rays and Magnetic Fields in Galaxy Clusters (March 12, 2018)

Bhaswati Bhattacharyya (NCRA-TIFR, Pune) A long-term study of Rotating Radio Transients (March 19, 2018)

Seminar

Sravani Vaddi (NCRA-TIFR, Pune) Ghost ionization in the cooling flow filaments of galaxy clusters (April 17, 2017)

Dipanjan Mukherjee (Australian National University) Simulating the jet-ISM interaction in GPS and CSS galaxies (September 19, 2017)

Deepthi Gorthi (University of California, Berkeley, USA) Building an FFT Correlator for the Hydrogen Epoch of Reionization Array (November 27, 2017)

Kshitij Thorat (Rhodes University, South Africa) Seize the means of reduction: Making Containerised Pipelines for Radio Interferometric Data (December 11, 2017)

Maitrayee Tiwari (Max Planck Institute for Radio Astronomy, Bonn, Germany) Unveiling the remarkable photodissociation region of M8 (December 15, 2017)

Ayan Acharyya (Australian National University, Australia) Inferring ISM conditions in high-z universe from rest-frame UV spectra I: applying UV diagnostics on bright lensed galaxy at z∼1.7 (December 19, 2017)

Kimberley Emig (University of Leiden, The Netherlands) Cold HI, near and far, with low-frequency recombination lines, January 12, 2018)

Kameswara Mantha (University of Missouri, Kansas City, USA) Towards a Robust Major Merger History of Massive Galaxies (February 16, 2018)

National Centre for Biological Sciences, Bengaluru

Christopher Bruhn (IFOM the FIRC Institute of Molecular Oncology, Milan, Italy) Metabolic Regulations by Genome Integrity Surveillance Checkpoints (25.04.2017)

Rishita Changede (Mechanobiology Institute, National University of Singapore) Nanoclusters of integrins underlie cell matrix adhesions (27.04.2017)

Akansha Sehgal (The Johns Hopkins School of Medicine, Baltimore, MD, USA) Brain tumor detection through CEST-MRI (12.05.2017)

Bard Ermentrout (Department of Mathematics University of Pittsburgh) Scent and Sensibility (15.05.2017)

Brett Seymoure (Fish, Wildlife, and Conservation Biology Department Colorado State University, Fort Collins, USA) Mimetic butterflies prefer light environments that correspond to visual sensitivities and microhabitat (16.05.2017)

Sakhthivel Sadayappan (Department of Internal Medicine, Heart, Lung and Vascular Institute, University of Cincinnati, Cincinnati, USA) Cardiac Myosin Binding Protein-C is a critical regulator of cardiac function (29.05.2017)

Prathamesh Turaga (Mathematics IMSI, Chenna), To Be or Knot to Be (09.06.2017)

Joyojeet Pal (School of Information University of Michigan) Double Feature: the Death, Life and Afterlife of Film in India

Pulak Kar (Department of Physiology, Anatomy and Genetics University of Oxford, United Kingdom) CRAC channels Ca2+ micro domains in NFAT activation and gene expression (19.06.2017)

Doug Sipp (RIKEN Centre for Developmental Biology) The case of the vanishing stem: Is “mesenchymal stem cell” a valid concept? (07.07.2017)


Paul Switzer (Department of Biological Sciences, Eastern Illinois University, Charleston, USA) Dragonflies in Space, 02.08.2017


Ashok Balasubramanyam (Vice President for Academic Integration and Senior Associate Dean for Academic Affairs Baylor College of Medicine, Houston, Texas) An Infectious Cause of Metabolic Disease: Lessons from HIV (26.07.2017)

Trevor Price (Department of Ecology and Evolution The University of Chicago, IL) The colour and colour vision of birds (31.07.2017)

Andrej Sali (Department of Pharmaceutical Chemistry University of California, San Francisco) Integrative modeling of biomolecular assembly structures and pathways (02.08.2017)

Sreejaja Nair (Department of Biological Sciences, Tata Institute of Fundamental Research) Maternal Reign on Vertebrate Embryogenesis – Good, Bad or Ugly? (02.08.2017)

Ullas Pedmale (Cold Spring Harbor Laboratory Cold Spring Harbor, NY) Mechanisms underlying light control of plant growth (08.08.2017)

Khushboo Rastogi (Department of Biochemical Engineering and Biotechnology, Indian Institute of Technology, New Delhi) Molecular mechanisms governing ensemble behaviour of myosin II motors under unloaded conditions (11.08.2017)

Sudip Kundu (Department of Biophysics, University of Calcutta) The landscape of co-evolutionary constraints in the sequence-space of biological macromolecules reflects their folding and assembly constraints (17.08.2017)

Rupamanjari Majumder (Laboratory of Experimental Cardiology, Department of Cardiology, Leiden University Medical Center, Netherlands) Islands of spatially discordant APD alternans trigger arrhythmogenesis in remodelled cardiac tissue by promoting electrotropic dys synchrony (21.08.2017)

Amitabha Bandopadhyay (Dept. of Biological Sciences & Bioengineering, IIT Kanpur) Dipole Organization and Membrane Biophysics: A Tale of Two Studies (22.08.2017)

Dhiraj Bhatia (Research Unit INSERM, Chemical Biology of
Membranes and Therapeutic Delivery, INSTITUT CURIE – Centre de Recherche) DNA based emerging technologies for biological and biomedical applications (25.08.2017)
Arjun Gopalaswamy (Statistics and Mathematics Unit, Indian Statistical Institute, Bangalore & Zoology, University of Oxford) Characterising Wildlife Populations: From Individuals to Landscapes (28.08.2017)
Babu Reddy J. N. (Developmental and Cell Biology Department University of California Irvine, CA USA) Molecular mechanisms behind the surprising force adaptation of motors on intracellular vesicles (04.09.2017)
Christine Orego (Structural & Molecular Biology, University College London) A Structural Perspective on the Evolution of Protein Functions (05.09.2017)
Dayananda Siddavattam (School of Life Sciences, University of Hyderabad) Logic Driven Science-Endless Conclusions: The Race Towards Elucidating the Physiological Role of Bacterial Phosphotriesterases (05.09.2017)
Prateek Tripathi (The Scripps Research Institute, La Jolla, CA) Understanding the mechanistic links between the circadian clock and plant metabolism for crop improvement (11.09.2017)
Karthik Raman (IIT, Madras) Computational approaches to understand and manipulate metabolic networks (14.09.2017)
Arvind Ramanathan (Buck Institute of Aging, California) The Role of Monomethylated Lipids, Arachidonic Acid Derived Lipids, and a Novel Glycolysis-JNK signaling axis in Aging (18.09.2017)
Yaakov (Koby) Levy (Computational Molecular Biophysics, Weizmann Institute of Science) Molecular principles for optimizing protein-DNA interactions (18.09.2017)
Rupamanjari Majumder (Laboratory of Experimental Cardiology, Department of Cardiology, Leiden University Medical Center, Netherlands) Islands of spatially discordant APD alternans trigger arrhythmogenesis in remodelled cardiac tissue by promoting electrotonic dyssynchrony (20.09.2017)
Markus Thamm (Department of Sociobiology and Behavioral Physiology Biocenter, University of Wuerzburg) Molecular mechanisms of social organisation in the honey bee colony (28.09.2017)
Teymur Kurzchalia (MPI-CBG Dresden) Stop-and-Go on metabolic highways or How C. elegans dauer larva survives desiccation (04.10.2017)
Sebastian Walter (Fellow of bangaloREsidency, Goethe Institute) Colour in My Mind: Science and Art (10.10.2017)
Amit Singhal (Singapore Immunology Network Agency for Science Technology and Research (A*STAR)) Harnessing host immunometabolic circuits to design TB HDTs (23.10.2017)
Andrew Carter (Structural Studies Division, MRC Laboratory of Molecular Biology, Cambridge) Transporting cargo over long distances: insights from Cryo-EM structures of dynein/dynactin (27.10.2017)
Swapnil V. Ghodge (Esthelman School of Pharmacy University of North Carolina, Chapel Hill, NC, USA) Discovery and Engineering of Enzyme Activities In Pursuit of New Antibiotics (31.10.2017)
Shivashankar G. V. (Nuclear Mechanics & Genome Regulation Laboratory Mechanobiology Institute, IFOM-NUS Chair Professor, National University of Singapore) Mechanical control of nuclear reprogramming & cell-fate decisions, (02.11.2017)
Gohda Goshima (Division of Biological Science, Nagoya University, Japan) Microtubules and motors in plants, (06.11.2017)
Antonio Jose Vidal-Puig (Wellcome Trust/MRC Institute of Metabolic Science University of Cambridge) Adipose tissue expandability, lipotoxicity and the metabolic syndrome (13.11.2017)
Vinay Bulusu (Research Associate Cancer Research UK, Beatson Institute) Spatiotemporal regulation of metabolism in embryonic development and cancer (14.11.2017)
Vivek Malhotra (Centre for Genome Regulation, Barcelona) Chaperone assisted unconventional protein secretion, (14.11.2017)
Ishier Raote (Centre for Genome Regulation, Barcelona) Building a machine for secretion of bulky collagens from endoplasmic reticulum (15.11.2017)
Amitabha Bandyopadhyay (Dept. of Biological Sciences & Bioengineering, IIT Kanpur) Candidate gene approaches in cartilage development research (16.11.2017)
Vignesh Kasinath (University of California, Berkeley) Epigenetic Repression by PRC2: Visualizing interactions with cofactors JARID2, AEBP2 and dinucleosomes by cryo-EM (21.11.2017)
Arne Elofsson (Department of Biochemistry and Biophysics, Stockholm University) Large scale de novo structure prediction of protein families using PconsC3 and ProQ3 (23.11.2017)
Deepak Modi (ICMR-National Institute for Research in Reproductive Health) Embryo Implantation: War in times of Love - Understanding the Maternal Control of Embryo Implantation to Early Placentation (05.12.2017)
Nitin S. Baliga (Institute for Systems Biology, Seattle, WA) Systems approach to cancer, infectious disease, the environment, and education (07.12.2017)
Sarah Bray (Department of Physics University of Warwick, UK) Collective motion and intelligence (12.12.2017)
Shana Elbaum-Garfinkle (The Graduate Center, CUNY, New York, USA) Phase behaviour of disordered proteins underlying low density and high permeability of liquid organelles (13.12.2017)
Nandini Krishnamoorthy (Harvard Medical School Brigham and Women’s Hospital Boston, MA, USA) Lung Regulatory T cells in Inflammation and tolerance (15.12.2017)
Shachi Katira (University of California, Berkeley, USA) A general mechanism for membrane-mediated forces of assembly between proteins: the order phobic effect (18.12.2017)
Vijay Tiwari (Developmental Epigenomics Laboratory, Institute of Molecular Biology (IMB)) Deciphering the Epigenetic Code of Brain Development and Function (18.12.2017)
Sourav Kumar Dey (Department of Pharmacology, Weill Cornell Medical College) Biochemical and single molecule studies of backbone branched RNAs and lariat debranching enzyme (Db1p) (19.12.2017)
Jeff Gore (Department of Physics, Massachusetts Institute of Technology USA) Building Microbial Communities from the Bottom Up (21.12.2017)
Nikta Fakhri (Department of Physics, Massachusetts Institute of Technology, USA) Symmetry and geometry in biological active matter (21.12.2017)
Karuna Sampath (Division of Biomedical Sciences Warwick Medical School, Coventry, UK) Coordinate Regulation of Development by a Shared RNA Element (26.12.2017)
Christos Papadimitriou (Columbia University, USA) A computer scientist thinks about the brain (29.12.2017)
L. Mahadevan (Harvard University, Cambridge, USA) First lecture on Inverse problems (01.01.2018)
L. Mahadevan (Harvard University, Cambridge, USA) Second lecture on Inverse problems (02.01.2018)
Colin W. Taylor (Department of Pharmacology, Cambridge University) Signaling to and from IP3 receptors (16.01.2018)
Francisco Hita Garcia (Okinawa Institute of Science and Technology, Okinawa, Japan) 3D ants and next-generation phenomics – how new imaging technologies change the role of morphology in 21st century entomology (22.01.2018)
Daniel St. Johnston (Gordon Institute, University of Cambridge, Cambridge, UK) Alternative modes of epithelial polarity (25.01.2018)
David Spiegelhalter (Statistical Laboratory Centre for Mathematical Sciences) Communicating science through the media: what could possibly go wrong? (08.02.2018)
Suhel Quader (Director and Scientist Nature Conservation Foundation) Engaging children and adults in documenting a changing world (09.02.2018)
Thomas Ruedel (Wuerzburg University) Subversion of innate immune responses by Chlamydia infection (19.02.2018)
Fred C. Dyer (Department of Integrative Biology, Michigan State University) Mechanisms and Evolution of Search Behavior in Bees (09.03.2018)
Seema Mundoli (School of Development, Azim Premji University) Archives Talk Series: Tracing Bengaluru’s water history: Understanding the past for a sustainable future (20.03.2018)
Jack Gray (Department of Biology, University of Saskatchewan) Inspiration from a tiny mind: Neural and behavioural mechanisms underlying collision detection and avoidance in an insect (26.03.2018)
Kenji Matsuno (Department of Biological Sciences, Graduate School of Science, Osaka University) Cell chirality drives left-right asymmetric morphogenesis (27.03.2018)
Masakazu Akiyama (Laboratory of Mathematical Modeling Research Institute for Electronic Science) A mathematical model of Drosophila hindgut (27.03.2018)

TIFR Centre for Interdisciplinary Sciences, Hyderabad
Mohinish Shukla (University of Massachusetts, Boston) Language learning as a constrained computation (January 2018)
Ravi Guti, Bramanandam Manavathi, Krishnaveni Mishra, Sharmistha Banerjee (University of Hyderabad) TIFR-UoH Life Sciences seminar series
Professors William Earnshaw (University of Edinburgh), Anne Spang (University of Basel), Sandra Schmid (UT Southwestern), Thomas Lecuit (Institute of Developmental Biology) EMBO Global Exchange Lecture Series talks (February 2018)
R. S. Praveen Kumar (Secretary, Telangana Social Welfare Residential Educational Institutions Society) Scientists and Neglected Generations, Cultural Colloquium, TIFR Centre for Interdisciplinary Sciences, Hyderabad (March, 2018)
Subhojit Sen (Centre for Excellence in Basic Sciences, Mumbai) Epigenetics (September, 2017)
Michael Sattler (Helmholtz Zentrum, Munich, Germany) Dynamics in biomolecular recognition studied by NMR and integrative structural biology (October, 2017)
Kevin Gardner (The City College of New York, USA) Controlling biochemical function via environmentally-modulated protein/protein interactions: Using biophysics to turn Nature’s switches into our tools (October, 2017)
Harald Schwalbe (University of Frankfurt, Germany) RNA-based regulation - Insights from NMR (February, 2018)
Dieter Suter (University of Dortmund, Germany) Velocity fields of non-Newtonian liquids from magnetic resonance microscopy (February, 2018)

Homi Bhabha Centre for Science Education, Mumbai
Abhijit Kumar Bezarulah (Independent consultant/ Founder Member, North East Information Technology Association) Regional plan & status of science education in schools in north east region of India (April 10, 2017)
Saurabh Basu (IIT Guwahati) Role of symmetries in fundamental physics (April 11, 2017)
Amogh Sinnoorkar (Central University of Karnataka) Towards a content based empirical epistem in physics (April 27, 2017)
Vinita Navalkar (Tata Institute of Fundamental Research, Mumbai) Astrophotography, Special talk at the Orientation-Cum-Selection Camp (OCSC) of Astronomy Olympiad (May 7, 2017)
Dipankar Bhattacharya (IUCAA, Pune) ASTROSAT: India’s space observatory, Valedictory Function of the Orientation-Cum-Selection Camp (OCSC) of Astronomy Olympiad (May 8, 2017)
Dilshad Ahmad (Tata Research Development & Design Centre) Low cost water purification solutions for Indian households (May 11, 2017)
Jugal Kishore Verma (Department of Mathematics, Indian Institute of Technology Bombay) An invitation to Ehrhart theory of lattice points in polytopes, IMOTC Award distribution Function (May 20, 2017)
Manjunath Krishnapu (Department of Mathematics, Indian Institute of Science, Bangalore) In praise of good definitions, IMOTC Award distribution Function (May 20, 2017)
A. A. Natu (IISER Pune) What we learn from nature, Valedictory Function of the Orientation-Cum-Selection Camp (OCSC) of Junior Science Olympiad (May 26, 2017)
Anita Patil (Ex-Medical Social Worker, BARC Hospital) Biological aspects and social stigmas on menstruation (June 2, 2017)
Vivek Polshettiwar (Tata Institute of Fundamental Research, Mumbai) Can nanotechnology help combat climate change, OCSC Chemistry Valedictory Function (June 3, 2017)
Pratap Raychaudhuri (Tata Institute of Fundamental Research,
Mumbai) Walking through walls: The amazing world of electron, OCSC Physics Valedictory Function (June 9, 2017)
Sanjay Sane (The National Centre for Biological Sciences, TIFR, Bengaluru) How do insects fly, OCSC Biology Valedictory Function (June 10, 2017)
Ajit Mohan Srivastava (Institute of Physics, Bhubaneshwar) Learning science, doing research, 3 Idiot’s Way (June 15, 2017)
Palash Baran Pal (Senior Professor, Saha Institute of Nuclear Physics, Kolkata) The history and mystery of calenders (June 15, 2017)
Melita Vaz (Independent researcher) Software for qualitative data management (June 16, 2017)
Sabyasachi Bhattacharyya (C.V. Raman University Professor, Assoka University, Sonepat, Haryana) India’s higher education crisis: What is to be done? (June 27, 2017)
Garga Chatterjee (Assistant Professor, Indian Statistical Institute, Kolkata) Visual learning in children after early vision deprivation (July 6, 2017)
Aswin Sai Narain Seshasayee (The National Centre for Biological Sciences, TIFR, Bengaluru) Genomics, postnational network and the Indian higher education system (July 13, 2017)
Sukant Saran (Tata Institute of Fundamental Research, Mumbai) Sculpting science: An experiment in art (July 27, 2017)
Ramith Nair (University of Leiden, The Netherlands) Precy adaptations to bacterial predation (August 3, 2017)
Indira Chowdhury (Centre for Public History, Srishti Institute of Art, Design and Technology, Bangalore) Science and the Creation of an ‘Elsewhere’: Bhabha’s international network and the creation of a climate of research at the Tata Institute of Fundamental Research (1945-1966) (August 17, 2017)
Ramji Tiwari (formerly Professor & Head, Department of Hindi, University of Mumbai, Mumbai) Hindi ka vartaman paridrishtya, on the occasion of Hindi Divas Function (September 14, 2017)
Sujatha Noronha (Bookworm Trust, Goa) Enabling reading relationships within the library (November 2, 2017)
Vivek Monteiro (Founder and Advisor, Navnirmiti Foundation) Role of science education in promoting scientific temper, Homi Bhabha Award Function (November 3, 2017)
Anagha Bhat (Ph.D. from Deccan College, Pune) Children, concepts of time and past, and history education in schools (November 16, 2017)
Ramasamy Venugopal (Office of Astronomy for Development, South Africa) Astronomy for a better world (December 7, 2017)
P. Patil (University of Mumbai) Adult and continuing education, for around 40 students, YCMOU PGdP workshop (December 10 and 17, 2017)
Rajendra Chetty (Cape Peninsula University of Technology, South Africa) Poverty, race and class in South African public education (December 21, 2017)
Rupamanjari Ghosh (Vice-Chancellor, Shin Nadar University, UP) Manipulating atoms by light, Felicitation function of the International Olympiad Medalists of 2017, Infosys Award Function (December 22, 2017)
Jailukmar Radhakrishnan (Tata Institute of Fundamental Research, Colaba) It is Entropy that counts, Felicitation function of the International Olympiad Medalists of 2017, Infosys Award Function (December 22, 2017)
John Lawrence Bencze (University of Toronto, Canada) Critical and active citizenship through science education, Post-epiSTEME7 workshop (January 9-10, 2018)
David Sokoloff (University of Oregon, Eugene, OR, USA) Active learning (ALOP) and Experimental problem solving in physics (January 10-12, 2018)
S. G. Dani (Centre for Excellence in Basic Sciences, Mumbai) What science entails, beyond practical science (January 13, 2018)
Christine Chambris (Université de Cergy-Pontoise, France) The concepts of place-value and unitizing in the learning of primary mathematics (January 31, 2018)
Jean Michel Delire (Haute École de Bruxelles-Brabant, Bruxelles) Ancient instruments and problems may help to teach mathematics today (February 15, 2018)
Paromita Vohra (Filmmaker, Writer, and Curator) Un-limited Girl - Talking Feminism and Film, Women’s day celebration organised by HBCSE Women Cell, HBCSE (March 13, 2018)
V. G. Kulkarni Memorial Lecture
Rohini Godbole (Professor, Centre for High Energy Physics, Indian Institute of Science, Bangalore) Women in Physics and Mathematics, Sixteenth V. G. Kulkarni Memorial Lecture, HBCSE, September 21, 2017*

Colloquia

Mathematics Colloquia

Nishant Chandgotia (Tel Aviv University, Israel) Irrational rotations, random affine transformations and the central limit theorem (06.04.2017)
Sang-hyun Kim (Seoul National University) Obstruction for a virtual C2-action on the circle (20.04.2017)
Mahan Mj (TIFR, Mumbai) Motions of limit sets (27.04.2017)
Jaikrishnan Janardhanan (Indian Institute of Technology, Madras) Finitess Theorems for Holomorphic Mappings from Products of Hyperbolic Riemann Surfaces (25.05.2017)
Anish Ghosh (TIFR, Mumbai) Values of quadratic forms (12.06.2017)
M.S. Raghunathan (IIT, Mumbai) The Narasimhan-Seshadri Theorem revisited (15.06.2017)
Madin Nori (University of Chicago, USA) Jordan Curve theorem (22.06.2017)
Rohit Nagpal (University of Chicago, USA) Representation stability and FI-modules (06.07.2017)
Florian Sprung (Princeton University, USA) Elliptic curves and the Birch and Swinnerton-Dyer conjecture (13.07.2017)
Sugata Mondal (Indiana University, Bloomington) Small Eigenvalues of Riemannian surfaces (03.08.2017)
Thomas Koberda (University of Virginia) The free product structure of diffeomorphism groups (10.08.2017)
Ekata Saha (TIFR, Mumbai) Transcendence of certain infinite series (17.08.2017)
Biswaajyoti Saha (TIFR, Mumbai) Multiple Stieltjes constants (24.08.2017)
Anand Sawant (University of Munich, Germany) Central extensions and A1-fundamental groups (14.09.2017)
Pranav Pandit (University of Vienna, Austria) From extremal
metrics and gradient flows to categorical Kähler geometry (28.09.2017)
Ashwin Deopurkar (TIFR, Mumbai) Tropical geometry of curves (02.11.2017)
Kalyan Banerjee (TIFR, Mumbai) Involutions on algebraic surfaces and algebraic cycles (09.11.2017)
Hengfei Lu (TIFR, Mumbai) The Prasad conjecture for PGSp(4) (16.11.2017)
Tohru Kohrita (TIFR, Mumbai) The representability of motivic cohomology (23.11.2017)
Patrice Philippon (Institut de Mathématiques de Jussieu, France) Arithmetic geometry of toric varieties (30.11.2017)
Efim Zelmanov (University of California, USA) Infinite dimensional superalgebras and their representations (07.12.2017)
Michel Waldschmidt (Institut de Mathématiques de Jussieu, France) Two invariants related to two conjectures due to Nagata (14.12.2017)
Laurent Fargues (Institut de Mathématiques de Jussieu, France) padic symmetric spaces (21.12.2017)
Subham Sarkar (TIFR, Mumbai) Extension of Mixed Hodge structures and Special values of Hypergeometric functions (04.01.2018)
Ved Datar (University of California, Berkeley) Kahler-Einstein metrics on Fano manifolds (11.01.2018)
Vincent Sécherre (Université de Versailles Saint-Quentin, France) Link representations of finite and algebr general linear groups (18.01.2018)
Maria Esteban (C.N.R.S. Université Paris-Dauphine) Rigidity, nonlinear flows and optimal symmetry for extremals of functional inequalities (23.01.2018)
Wilfried Schmid (Harvard University, USA) Hodge theory and unitary representations of reductive groups (25.01.2018)
Michael Barany (Dartmouth College, USA) Making a Global Mathematician (08.02.2018)
Mikhail Borovoi (Tel Aviv University, Israel) Cayley groups (15.02.2018)
Seonheec Lim (Seoul National University) Hausdorff dimension in inhomogeneous Diophantine approximation (22.02.2018)
M.V. Vannathan (IIT, Mumbai) Optimal Design Problems and Beyond (01.03.2018)
Madhusudan Manjunath (IIT, Mumbai) Riemann-Roch, Graphs, Lattices and Free Resolutions (08.03.2018)
Takuro Mochizuki (ICTS, Bangalore) Stability/Instability Analysis of Real matrices from their Sign eigenfunctions (August 8, 2017)

Eric Todd Quinto (Tufts University, USA) Artifacts in Arbitrary Limited Data Tomography Problems. (July 25, 2017)
Vishal Vasan (ICTS, Bangalore) An introduction to the unified transform method and applications. (August 22, 2017)
Shivasubramanian Gopalakrishnan (IIT, Bombay) Modeling urban scale coastal inundations using a coupled Discontinuous Galerkin -- Smooth Particle Hydrodynamics approach. (September 19, 2017)
Sunder Ram Krishnan (Technion, Israel) Convergence of the Reach for a Sequence of Random Manifolds. (September 26, 2017)
Isidro Munive (CIMAT, Mexico) The Dirichlet problem in the Heisenberg group. (October 10, 2017)
P.N. Srikanth (TIFR-CAM, Bangalore) Symmetries, Group action and their effect on concentration of Solutions for a class of Semilinear Elliptic Differential Equations. (October 31, 2017)
Salkat Mazumdar (The University of British Columbia) Blow-up Analysis for a Nonlinear Elliptic Equation with Critical growth and Hardy weight. (December 12, 2017)
Ved Datar (University of California, Berkeley) Kahler-Einstein metrics on Fano manifolds. (January 2, 2018)
Shibi Vasudevan (ICTS, Bangalore) The Arnold stability theorems for the 2D alpha Euler equations. (February 27, 2018)
Rama K. Yadavalli (Dept. of Mechanical and Aerospace Engineering The Ohio State University, Columbus) Hurwitz Stability/Instability Analysis of Real Matrices from their Sign Patterns With Applications. (March 6, 2018)
Naren Naik (IIT, Kanpur) Fluorescence optical tomography: Some directions and results. (March 13, 2018)

### Theoretical Physics Colloquia

Surch Dor (Institute for the Physics and Mathematics of the Universe, Japan) Science with the Subaru telescope: from primordial black holes to Planet Nine (April 11, 2017)
Zohar Komargodski (Simons Centre for Geometry and Physics, Stony Brook University, New York, U.S.A) Using Topology to Solve Strongly Coupled Quantum Field Theories (April 18, 2017)
Prasad Hegde (Centre for High Energy Physics, Indian Institute of Science, Bangalore) Supercomputing the properties of the quark-gluon plasma (May 2, 2017)
Diptimoy Ghosh (Weizmann Institute of Science, Israel) Symmetries and Hierarchies of the Standard Model (July 18, 2017)
Biswajit Pandey (Visva Bharati University, Kolkata) How much does a galaxy know about its large-scale environment? (August 29, 2017)
Hugo Touchette (National Institute for Theoretical Physics (NITheP), Stellenbosch, South Africa) Large deviation theory: From physics to mathematics and back (September 12, 2017)
Pierre Le Doussal (ENS, Paris) Memory effects in Kardar Parisi Zhang growth: exact results via the replica Bethe ansatz
STCS Colloquia /Faculty Seminars

N. Touzi (École Polytechnique, France) Continuous-time Principal-Agent Problem: A Stackelberg Stochastic Differential Game (04/04/2017)

N. Karamchandani (Indian Institute of Technology, Mumbai) Content Caching and Delivery with Partial Adaptive Matching (25/04/2017)

R. Mazumdar (University of Waterloo, Canada) Insensitivity of the Mean Field of Loss Systems Under Randomized SQ(d) Algorithms (02/05/2017)

T. Kavitha (STCS, TIFR) Popular Matchings in the Stable Marriage Problem (05/09/2017)

P. Netrapalli (Microsoft Research, Bangalore) Accelerating Stochastic Gradient Descent (19/09/2017)

C. Mukherjee (New York University, U.S.A) Compactness and Large Deviations (03/10/2017)

M. Thattai (National Centre for Biological Sciences, Bangalore) Possible and Impossible Cells (10/10/2017)

Khare (Indian Institute of Science, Bangalore) The Critical Exponent: A Novel Graph Invariant (17/10/2017)

S. Agrawal (Indian Institute of Technology, Chennai) New Constructions for Reusable Garbled Circuits (23/10/2017)

N. Limaye (Indian Institute of Technology, Mumbai) Small-depth Multilinear Formula Lower Bounds for Iterated Matrix Multiplication, with Applications (28/11/2017)

P. Harsha (STCS, TIFR) Agreement tests on Graphs and Hypergraphs (30/11/2017)

S. Srinivasan (Indian Institute of Technology, Mumbai) An Exponential Depth-Hierarchy Theorem for Constant-Depth Multilinear Circuits (05/12/2017)

M. Mandjes (University of Amsterdam, The Netherlands) Overdispersion and Multi-timescale Models: Exact Asymptotics (23/01/2018)

P. S. Joshi (TIFR) Recent Developments on Gravitational Collapse (06/02/2018)

S. Krishnasamy (STCS, TIFR) Learning and Scheduling in Queueing Systems (13/02/2018)

Wednesday Colloquia

R. V. Hosur (Department of Chemical Sciences, TIFR) Stretching the limits of Solution NMR (28 Mar 2018)

Mark Riley (Raymond K. Bloch Professor of Physics, Florida State University, U.S.A) Gamma-Ray Spectroscopy and the Ever-Fascinating World of the Atomic Nucleus (14 Mar 2018)


Vaskar Saha (University of Manchester, UK & Tata Translational Cancer Research Centre, Kolkata) Response Heterogeneity in Cancer - The Acute Lymphoblastic Leukaemia Paradigm (28 Feb 2018)

Subi J. George (Supramolecular Chemistry Group, New Chemistry Unit, JNCASR, Bangalore) Bio-Inspired, Temporally Programmed Molecular Assemblies (21 Feb 2018)

R. G. Pillay (DNAP, TIFR) Highlights of research activities over four decades at TIFR (14 Feb 2018)

Jyotishman Dasgupta (DCS, TIFR) Photoactivating C-H bonds inside Artificial Photoenzymes (07 Feb 2018)

Edmond Iancu (Institut de Physique Theorique de Saclay, Paris) Jet evolution in a dense QCD medium (31 Jan 2018)

W. T. F. den Hollander (Leiden University, Netherlands) Exploration on Dynamic Networks (24 Jan 2018)

Pushan Ayyub (DCMP&MS, TIFR) The third paradigm of nanoscience (17 Jan 2018)

Gyan Bhanot (Rutgers University, New Jersey, U.S.A) Treating cancer, one person at a time (10 Jan 2018)

Manfred Lindner (Max Planck Institut fuer Kernphysik, Heidelberg) The Search for Dark Matter in the Universe (13 Dec 2017)

B. S Acharya (DHEP, TIFR) Ground based Gamma Ray Astronomy (06 Dec 2017)

Thomas Pucadyil (IISER, Pune) Ground based Gamma Ray Astronomy (06 Dec 2017)

Thomas Henning (Max Planck Institute for Astronomy, Heidelberg) Physics of Star Formation (22 Nov 2017)

Gagandeep Kang (Translational Health Science & Technology Institute, Faridabad) Must do better-oral vaccines in the developing world (15 Nov 2017)

Bruce Rafael Mellado Garcia (University of the Witwatersrand, South Africa) The discovery of a Higgs boson and the quest for new bosons at the LHC (08 Nov 2017)


Nitin Nitsure (School of Mathematics, TIFR) A geometric framework for dynamics with unilateral constraints and friction (18 Oct 2017)


Hiyaa Ghosh (NCBS-TIFR, Bangalore) The adult mammalian brain and a multifaceted transcription factor (04 Oct 2017)

Jorge Kurchan (Ecole Normale Superieure) Large dimension approximation: from atomic physics to the glass transition (27 Sep 2017)

Ullas Kolthur (DBS, TIFR) Food for thought: all about life, reproduction, disease and death (20 Sep 2017)

Cooperation (13 Sep 2017)

G. Baskaran (IMSc, Chennai) Elements of Surprise at TIFR (06 Sep 2017)


Ayan Banerjee (IISER, Kolkata) Optical tweezers: building bridges between the micro and macro worlds (23 Aug 2017)

K. Dharmalingam (Aravind Medical Research Foundation, Madurai) Ocular Diseases: Prediction, Prevention and Basic Research (16 Aug 2017)

K. P. Singh (ex-DAA, TIFR) X-ray Spectroscopy in Astronomy (09 Aug 2017)

G. Ravindra Kumar (DNAP, TIFR) Tabletop Plasma Gets Wind of Solar Turbulence (02 Aug 2017)

Vijay B. Shenoy (IISc, Bangalore) Topology of Electronic Phases (26 Jul 2017)

Vaibhav Prabhuudesai (DNAP, TIFR) Physics of electron induced chemistry (19 Jul 2017)

Pawan Kumar (Univ of Texas, Austin, USA) Spectacular Explosive Events in the universe associated with black holes and neutron stars (12 Jul 2017)

Gotam K. Jarori (Department of Biological Sciences, TIFR) Plasmodium Enolase: A Novel Candidate for a Multi Stage Broad spectrum anti-malarial Vaccine (03 May 2017)

Gotam K. Jarori (Department of Biological Sciences, TIFR) Plasmodium Enolase: A Novel Candidate for a Multi Stage Broad spectrum anti-malarial Vaccine (03 May 2017)

C. M. Reddy (IISER, Kolkata) Mechanically Responsive Dynamic Molecular Crystals (19 Apr 2017)


ASET Colloquia

Shrikrishna Gupta (Technology Transfer & Collaboration Division, BARC, Mumbai) DAE: Spin-off Technology Transfer Procedures and its Benefits (23 Mar 2018)

Rishikesha Krishnan (Indian Institute of Management Indore) Bridging the Gap between Research & Societal Impact (09 Mar 2018)

Hemant Adarkar (Digital Venture, The Nainital Bank Ltd) Bitcoins, Blockchain and Beyond... (23 Feb 2018)

Roop Mallik (Department of Biological Sciences, TIFR, Mumbai) Single Molecule Techniques (16 Feb 2018)

Ravi Kuchimanchi (Association for India’s Development) Towards understanding grassroots India (09 Feb 2018)

Tejal Kanitkar (TISS, Mumbai) India and the Paris Agreement – Concerns and a Possible Way Forward (02 Feb 2018)

Subhendu Ghosh (IUAC, New Delhi) Development of Delhi Light Source (DLS) at IUAC (19 Jan 2018)

Prachi Katre (Independent Consultant) Is food a solution to hunger: Are we missing a secret ingredient? (12 Jan 2018)

Vishal Mehrotra (Global Head – Open Source Platform, TCS, Mumbai) Nudges of open source to digital transformation (29 Dec 2017)

Sivaraj Sivaramakrishnan (University of Minnesota, USA) Bridging the information transfer gap: How weak protein interactions shape signal transduction (22 Dec 2017)

Joe Philip Ninan (Department of Astronomy & Astrophysics, Pennsylvania State University, USA) In search of Exo-earths: Development of next generation extreme precision radial velocity spectrographs (19 Dec 2017)

Vincenzo Piuri (Università degli Studi di Milano, Italy) Computational Intelligence for Biometrics (15 Dec 2017)

Amitabh Banerji (Institute for Chemistry Education, University of Cologne, Cologne, Germany) Teaching Organic Electronics: Hands-on experiments making LEDs and solar cells with organic semiconductors (08 Dec 2017)

Debabrata Maity (IIT Bombay) Designing of templates to reach the distal C-H bond (30 Nov 2017)


Vivek Datar (Project Director, INO, TIFR, Mumbai) Noble prizes in Nuclear Physics (01 Nov 2017)

Anil Kumar (DCMP@MS, TIFR, Mumbai) Production and measurement techniques of ultra low temperatures (03 Nov 2017)

Avinash Kale (UM-DAA Centre for Excellence in Basic Sciences) Deciphering the structural dogma of biological systems using Integrative Structural Biology (27 Oct 2017)

Kriti Ramamirtham (Dept of CSE, IIT Bombay) Towards a Theory to deal with smartness (13 Oct 2017)

Shalahb Gupta (IIT Bombay) High-speed data communication links for high energy physics experiments (06 Oct 2017)

Clare Waterman (Cell Biology and Physiology Center, National Heart, Lung and Blood Institute, National Institutes of Health, USA) Looking under the hood of the cell migration engine with high resolution microscopy (22 Sep 2017)

VijayRaghavan K (Secretary, DBT, Government of India) Growth, Form, Function (15 Sep 2017)

Amit Lad (DNAP, TIFR) Catching a plasma blow hot and cold on an ultrafast timescale (08 Sep 2017)

Indira Chowdhury (Centre for Public History, Srishti Institute of Art, Design and Technology, Bengaluru) The predicaments of institutional legacy: Archival oral histories of TIFR and what they tell us (18 Aug 2017)

Ullasa Kodandaramaiah (IISER Trivandrum) Evolution of ‘conspicuous’ colours in lizards (11 Aug 2017)

Abhay Deshpande (Stony Brook University) The Science and Status of The Electron Ion Collider (10 Aug 2017)

Rohini Balakrishnan (Centre for Ecological Sciences, IISc) Forest acoustics: Communication in the cacophony (04 Aug 2017)

M. S. Bhatia (Dean, Ramnarain Adik Institute of Technology, Neral) Laser Isotope Separation: A 21st century technology (28 Jul 2017)

Kukjin Chun (Seoul National University) MEMS technology based modern sensors and actuators (21 Jul 2017)

Yotishishan Dasgupta (DCS, TIFR) Raman Tracking of Photoinduced Charge Transfer States in Molecular Systems (14 Jul 2017)

Peter Garretson (Air Command and Staff College (ACSC)) Dr. Namrata Goswami, Great Power Attitudes and Aspirations toward Expansionism, Territoriality and Resource Nationalism in Space (10 Jul 2017)

Sukant Saran (TIFR) Colourful Stories (30 Jun 2017)

Neelima Khairatkar Joshi (NCEO: Drug Discovery, Gloucester Research Centre, Navi Mumbai) Evolution of Therapeutics – From Adam and Eve to Us (23 Jun 2017)

Ajay Parikh (WIPROD) Materials and methods of the Metal Additive Manufacturing (09 Jun 2017)

Vinita Navalkar (DAA, TIFR) Astrophotography: The art of catching the light!! (02 Jun 2017)
Priya Yadav: Designing Azurin Mutants Polygene to get Deeper Insights into Mechanical Properties of Azurin (July 24, 2017)
Ramiz Shahkhl: Bio-nanoconjugation of Mutant Cytochrome P450cam (CYP101) for electro-biocatalysis (September 11, 2017)
Shreetsama Karmakar: Femtosecond Stimulated Raman Spectroscopy as a New Tool to Identify Twisted Intramolecular Charge Transfer States (November 27, 2017)
Alok Kumar Tripathi: Synthesis of TEMPO linked Chromophore Molecules and Their Photophysical Quenching (December 18, 2017)
Aakita Das: Organic Photocatalysis inside Water-Soluble Supramolecular Cages (January 8, 2018)
Nita Ghosh: Elucidating the Reaction Coordinate for Charge Transfer Dynamics in Organic Donor-ACCEPTor Frameworks (January 29, 2018)
Mona Gupta: Exploring the mechanical properties of Ubiquitin-CUE2 complex (February 5, 2018)
Amitava Chandra: Tracking Phospholipid Induced Coil-Helix Transitions in Phosphoinositide-binding Motifs of Actin Binding Proteins (February 12, 2018)
Ananya Rakshit: Development of mixed N, O donor ligands for in vivo metal ion chelation and sensing (February 22, 2018)
Sanjoy Paul: Extracting the features of complex multidimensional energy landscape of proteins: a reaction coordinate free approach (February 26, 2018)
Anirban Das: Xeno-nuclei enable protein-specific modulation of order-disorder transition (March 5, 2018)
Ayan Maity: High Surface Area Aluminosilicates: Novel synthesis and unraveling the active sites by catalysis and Solid State NMR (March 12, 2018)
Yukti Arora: Seminal Electrode Materials for Battery and Supercapacitor Applications (March 26, 2018)

Department of High Energy Physics

Prabir Banik: Cosmic rays at PeV energies (26 March 2018)
Reetajyoti Moharana: High energy astrophysics during the multi-messenger era (26 March 2018)
Sobam Bhatnag: Stop search in tau final states and prospects of using the HO Calorimeter for L1 muon triggering at the CMS experiment (19 March 2018)
Harrison B Proper: Machine Learning in Particle Physics (3/3) (15 March 2018)
Harrison B Proper: Machine Learning in Particle Physics (2/3) (15 March 2018)
Harrison B Proper: Machine Learning in Particle Physics (1/3) (15 March 2018)
Simran Chatterjee: Radius scan for inclusive jets in CMS experiment (12 March 2018)
Raveendra Babu Karnam: Tracker related activities & top-quark mass measurements for the CMS experiment (26 February 2018)
Sunit Dogra: Bose-Einstein correlation measurements at CMS (23 February 2018)
Ramprasad Adak: R&D of GEM-based Muon Chamber Detector for the Compressed Baryonic Matter experiment at FAIR (13 February 2018)
Ravi Kuchimanchi: Leptonic CP phase test for Left-Right Symmetric Model (9 February 2018)
Anmit Shukla: Short-Time-Scale Gamma Ray Variability in CTA 102 (08 January 2018)
Saranya Ghosh: Search for associated production of Higgs boson in diphoton decay channel at CMS (01 January 2018)
Vaidhii Sharan Paliya: Jetted Active Galactic Nuclei in the Era of Fermi Gamma-ray Space Telescope (22 December 2017)
Saurabh Sandhija: One ring to bring them all (13 December 2017)
Karim Travieso: Search for physics beyond the standard model using charged lepton (04 December 2017)
Stefan Schlenstedt: Gamma-ray astronomy in preparation of the Cherenkov Telescope Aaray (21 November 2017)
Swagata Mukherjee: Search for exotic new physics in CMS (20 November 2017)
Isobel Ojeda: Observation of the Higgs Decaying to a Pair of Tau Leptons (13 November 2017)
Debasish Subroto: Search for lepton flavour violating tau decays (03 October 2017)
Harshal Panyala: Search for Galactic PeV Gamma Rays with IceCube Neutrino Observatory (31 July 2017)

Homi Bhabha Centre for Science Education, Mumbai

Seminars at Annual Research Meet, March 6 - 8, 2018

A. Dolas: Summer camp activities for developing language and creativity in students
C. Navane: Theories pass, the frog remains: A foray into the philosophy of biology
C. Ureskar and J. Sivaraman: A framework for students’ understanding of invariance in proportion problems across grades
D. Karnane: Limitations in paper-based textbooks and students’ struggle with vectors
G. Kaur (Homi Bhabha Fellow): Error detection and design negotiation in Kashmiri carpet weaving
G. Single: Student questioning in student-student discourse: Understanding the process and its role in doing science
K. K. Mashood: To see a world: Using multiple metaphors in science education
J. Advani and R. Shaikh: Roles of instant messaging environment in knowledge construction in CUBE program
P. Sivaramakrishnan (Assistant Professor, St. Xavier's Institute of Education): Global citizenship through service learning
R. D’ounga: What could social theories of disability mean for critical mathematics education?
R. Karundkar: Lessons from teachers’ interviews: A milestone in participatory action research
R. Shinde and T. Adangale: Development and use of worksheets with students to facilitate learning and assessment
R. Varkey: Some educational challenges to elementary agricultural education put forth by participatory approaches
S. Naik: Connecting mathematics in representations: Teaching multiplication and division of fractions
S. Narvekar and I. Das: Can we design interesting chemistry experiments using qualitative tests?
S. V. Varadarajan: Doing science: Making a start for primary and middle school students

In-house talks
A. Raveendran: Conceptualising critical science education using socio-scientific issues, PhD thesis Seminar, October 6, 2017
C. Narare: The visual rhetoric of biology, Research Proposal Seminar, February 14, 2018
D. Gupta: Early to bed, early to rise...? Thursday Seminar Series, November 30, 2017
D. Karnam: An analysis of the treatment of vectors in two higher secondary school curricula in India, Thursday Seminar Series, May 18, 2017
V. Agrawal and D. Karnam: Bringing the textbook to life: dynamic and interactive simulations to support model-based imagination and reasoning, August 31, 2017
P. Pande: Rethinking representational competence: Cognitive mechanisms, empirical studies, and the design of a new media intervention, Ph.D. Synopsis Seminar, October 31, 2017
R. Karandikar: Socio-scientific issues and current scenario on menstrual awareness at the global level, June 2, 2017
S. Shome: Educating educators: A narrative of working with the public education system, Thursday Seminar Series, May 25, 2017
S. Varadarajan: Problem-based learning approach to undergraduate chemistry laboratory education, Research Proposal Seminar, February 14, 2018

STCS Students Seminars
N. Mande: Dual Polynomials and Communication Complexity of XOR Functions (14/04/2017)
S.V. Tirodkar: On the Communication and Streaming Complexity of Maximum Bipartite Matching (21/04/2017)
U. Girish (Chennai Mathematical Institute, Chennai): On Leonid Gurvits’s Proof for Van der Waerden Conjecture (05/05/2017)
S. Agrawal: Stochastic Dominance (SD) and its Application to Enhanced Indexation (12/05/2017)
P. Chatterjee: Time-Space Lowerbound for SAT (19/05/2017)
R. Saptharishi: Using Git for Writing Papers (26/05/2017)
P. Pawar (School of Mathematics, TIFR): The Snake Lemma (02/06/2017)
S. Sherif: A Composition Theorem for Randomized Query Complexity (09/06/2017)
S. Velusamy (Indian Institute of Technolog, Madras): Streaming Complexity of Approximating Max 2CSP and Max Acyclic Subgraph (16/06/2017)
A. Tengse: Algebraic Branching Programs - Nisan’s Characterization and Identity Testing (23/06/2017)
V. Narayanan: Universal Composability of Secure Multi-party Computation Protocols (30/06/2017)
S. Chakraborty: Convex Split Lemma and it’s Application to Message Compression (07/07/2017)
A. Deo: Credit Risk: Simple Closed Form Approximate Maximum Likelihood Estimator (21/07/2017)
S. Sherif: A Lower Bound for Perceptrons that Compute Some Separation Problem (28/07/2017)
S. Bhosale: Method of Containers (11/08/2017)
N. Mande: Using Bispectrum Invariants to Classify Translated and Rotated Images (18/08/2017)
G. R. Karri: On Shannon’s Zero Error Capacity of a Graph (01/09/2017)
G. Kumar: Is Submodularity Testable? (08/09/2017)
T. M. Melli: On Circuit Depth of Symmetric Boolean Functions (15/09/2017)
A. Tengse: Quasipolynomial Hitting Sets for Circuits With Restricted Parse Trees (06/10/2017)
N. Mande: On the Fourier Spectrum of MOD Functions (13/10/2017)
V. S. Sharma: Membership Problem in Bit Probe Model (20/10/2017)
S.V. Tirodkar: Maximum Matching in the Semi-Streaming Model in Constant Number of Passes (27/10/2017)
A. Deo: Optimal Control and the Hamilton-Jacobi-Bellman PDE (03/11/2017)
V. Narayanan: Entropy Versus Pairwise Independence (10/11/2017)
M. Vingale: A Biased Introduction to Proof Complexity (17/11/2017)
S. Chakraborty: Entanglement Distillation in Quantum Information Theory (24/11/2017)
B. Satishdananandan (Texas A&M Univ., USA): Security of Cyber-Physical Systems (22/12/2017)
P. Dey: On the Exact Amount of Missing Information that makes Finding Possible Winners Hard (29/12/2017)
K. Gajjar: Parametric Shortest Paths in Directed Graphs (05/01/2018)
P. R. Lalakapuri: Representation of Finite Games as Congestion Games (19/01/2018)
A. Nema: A Scheme to Achieve One Shot Information Spectrum Divergence Rate Using Collision Relative Entropy for a Point to Point Classical - Quantum (c-q) Channel (02/02/2018)
G. R. Karri: A Technique for Verifying Markov Relations via Undirected Graphs (16/03/2018)
S. Sherif: The Approximate Degree of Subjectivity (23/03/2018)
The University Cell, along with Subject Boards in Biology, Chemistry, Computer and System Sciences, Mathematics, Physics and Science Education, administers the academic programme at TIFR.

In the year 2017-18, the number of different degrees conferred was as follows:

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Ph.D.</th>
<th>M.Sc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics</td>
<td>21 (TIFR-17, NCRA-2, TCIS-2)</td>
<td>13 (TIFR-10, NCRA-2, TCIS-1)</td>
</tr>
<tr>
<td>Chemistry</td>
<td>9 (TIFR)</td>
<td>--</td>
</tr>
<tr>
<td>Biology</td>
<td>21 (DBS-5, NCBS-16)</td>
<td>17 (NCBS-13, DBS-4)</td>
</tr>
<tr>
<td>Mathematics</td>
<td>11 (CAM-4, TIFR-7)</td>
<td>4 (CAM)</td>
</tr>
<tr>
<td>Computer Science</td>
<td>4 (TIFR)</td>
<td>2 (TIFR)</td>
</tr>
<tr>
<td>Science Education</td>
<td>--</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>66</strong></td>
<td><strong>36</strong></td>
</tr>
</tbody>
</table>

During the year 2017-18, 27 students registered for M.Sc degree. 58 students from the PhD Programme, and 35 students from the Integrated MSc-PhD programme registered for PhD degree.

The Nationwide Entrance Examination was conducted on December 10, 2017 in 30 centres across the country for admissions to GS-2018. Nearly 23000 students appeared for the test and the selection is under process.

A Visiting Students Research Programme in Biology, Chemistry, Computer & System Sciences, Physics and Mathematics was conducted in the summer of 2016 from May 8, 2017 to July 5, 2017. This programme enables students from around the country, most of whom are in the pre-final year of their M.Sc., to participate in research projects and get an exposure to the challenging research programmes under way at TIFR. These students work with a guide and attend regular seminars on frontier areas of science. 73 students participated in the VSRP 2017. Additionally, 2 Indian Academy of Sciences sponsored students also participated in VSRP – 2017.

The Academic Council, the overall governing body for the TIFR Deemed University, met on September 1, 2017 and February 16, 2018.

The process of MHRD approval of the TIFR-H campus was completed. The UGC team visited Hyderabad (both the old and the new campus) during April 29-30, 2017. The MHRD Notification was published in the Gazette on Aug 25th, 2017.

TIFR applied for the Institution of Eminence status in Dec 2017, the outcome is still awaited.

TIFR applied for the “Categorization of Universities for Graded Autonomy” in March 2018. The status of category-I Deemed-to-be University was obtained in May 2018.

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**Staff**

S. Krishnamurthy - Assistant Registrar (Academic), Benedict D’souza, Alka Bhoir, Bindu Jose, Pritam Dighe
Graduate Courses

Mathematics

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algebra (36 lectures)</td>
<td>E. Ghate</td>
</tr>
<tr>
<td>Topology (31 lectures)</td>
<td>S. Subramanian</td>
</tr>
<tr>
<td>Analysis (33 lectures)</td>
<td>S. Bhattacharya</td>
</tr>
<tr>
<td>Algebra (29 lectures)</td>
<td>Raja Sridharan</td>
</tr>
<tr>
<td>Topology (27 lectures)</td>
<td>Arvind Nair</td>
</tr>
<tr>
<td>Analysis (26 lectures)</td>
<td>A. Sankaranarayanan</td>
</tr>
<tr>
<td>Introduction to Algebraic Stacks (13 lectures)</td>
<td>Nitin Nitsure</td>
</tr>
<tr>
<td>Geometry for Physics (16 lectures)</td>
<td>Nitin Nitsure</td>
</tr>
<tr>
<td>Dynamical Systems on homogeneous spaces of Lie groups (36 lectures)</td>
<td>Anish Ghosh</td>
</tr>
</tbody>
</table>

TIFR Centre for Applicable Mathematics, Bengaluru

**Aug – Dec 2017**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complex Analysis</td>
<td>Sivaguru</td>
</tr>
<tr>
<td>PDE II</td>
<td>Shyam Sundar Ghoshal</td>
</tr>
<tr>
<td>Probability</td>
<td>Imran Biswas</td>
</tr>
<tr>
<td>Numerical Analysis</td>
<td>Praveen C.</td>
</tr>
<tr>
<td>Real Analysis</td>
<td>Prashanth S</td>
</tr>
<tr>
<td>Topology</td>
<td>Agnid Banerjee</td>
</tr>
<tr>
<td>ODE</td>
<td>K. Sandeep</td>
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<tr>
<td>Linear Algebra</td>
<td>Divyang Bhimani</td>
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**Jan – April 2018**

<table>
<thead>
<tr>
<th>Course Name</th>
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</tr>
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<tbody>
<tr>
<td>Measure and Integration</td>
<td>Ujjwal Koley</td>
</tr>
<tr>
<td>Algebra</td>
<td>Adimurthi</td>
</tr>
<tr>
<td>PDE I</td>
<td>Venkateswaran P. Krishnan</td>
</tr>
<tr>
<td>Functional Analysis</td>
<td>K.T.Joel</td>
</tr>
<tr>
<td>Differential Geometry</td>
<td>C.S.Aruna</td>
</tr>
<tr>
<td>Mechanics</td>
<td>A.S.Vasudevanurthy</td>
</tr>
<tr>
<td>Computational Methods</td>
<td>G.D.Veerappa Gowda</td>
</tr>
<tr>
<td>PDE III</td>
<td>Mythily R.</td>
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</table>

**Physics**

**Autumn 2017 (August 17–December 17)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematical Methods</td>
<td>G. Mandal</td>
</tr>
<tr>
<td>Classical Mechanics</td>
<td>A. Dihe</td>
</tr>
<tr>
<td>Quantum Mechanics I</td>
<td>S. Raychaudhuri</td>
</tr>
<tr>
<td>Electrodynamics I</td>
<td>V. Prabhudesai</td>
</tr>
<tr>
<td>Electrodynamics II</td>
<td>S. Majumdar &amp; A. Gopakumar</td>
</tr>
<tr>
<td>Experimental Methods I</td>
<td>S. Prabhu &amp; R. Palit</td>
</tr>
<tr>
<td>Experimental Methods III</td>
<td>S. Prabhu &amp; R. Palit</td>
</tr>
<tr>
<td>Particle Physics</td>
<td>K. Mazumdar</td>
</tr>
<tr>
<td>Nuclear Physics</td>
<td>I. Mazumdar</td>
</tr>
<tr>
<td>Astronomy &amp; Astrophysics I</td>
<td>S. Bhattacharya</td>
</tr>
<tr>
<td>Adv. Quantum Mechanics</td>
<td>N. Mathur &amp; R. Sharma</td>
</tr>
</tbody>
</table>
### Atomic and Molecular Physics
- D. Misra
- S. Minwalla

### General Theory of Relativity
- T. Roy

### Physics of the Standard Model I
- P. Raychaudhuri

### Superconductivity
- G. Mohanty

### A Course in Experimental High Energy Physics
- S. Minwalla

**Spring 2018 (Jan 18 - May 18)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Computational Physics</td>
<td>S. Raychaudhuri</td>
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<tr>
<td>Statistical Mechanics</td>
<td>R. Sensarma</td>
</tr>
<tr>
<td>Quantum Mechanics II</td>
<td>V. Tripathi</td>
</tr>
<tr>
<td>Experimental Methods II</td>
<td>R. Palit</td>
</tr>
<tr>
<td>Solid State Physics</td>
<td>K. Maiti</td>
</tr>
<tr>
<td>Quantum Field Theory I</td>
<td>R. V. Gavai</td>
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<tr>
<td>Fluid Mechanics I</td>
<td>S. Hanasage</td>
</tr>
<tr>
<td>Topological Aspects in Condensed Matter</td>
<td>M. Deshmukk</td>
</tr>
<tr>
<td>Physics of the Standard Model II</td>
<td>T. Ray</td>
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<tr>
<td>Astronomy &amp; Astrophysics II</td>
<td>Manoj Puravankara</td>
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### Chemistry

**Autumn 2017 (July 17 - December 17)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Introduction to Programming in ‘C’</td>
<td>A.S.R. Koti</td>
</tr>
<tr>
<td>Organic and Inorganic Chemistry</td>
<td>Ankona Datta</td>
</tr>
<tr>
<td>Mathematical Methods</td>
<td>Ravindra Venkatramani</td>
</tr>
<tr>
<td>Quantum Chemistry</td>
<td>Jyotishman Dasgupta</td>
</tr>
<tr>
<td>Materials Chemistry</td>
<td>Deepa Khushalani</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Deepa Khushalani/ A.S.R. Koti/ Ravindra Venkatramani/ Ankona Datta/ Sudipta Maiti/ Vivek Polshettiwar/ S. J. Wategaonkar</td>
</tr>
</tbody>
</table>

**Spring 2018 (January 18 - May 18)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>Optical Spectroscopy of Molecules</td>
<td>S. Maiti</td>
</tr>
<tr>
<td>Symmetry in Chemistry</td>
<td>Ranjan Das</td>
</tr>
<tr>
<td>Nanochemistry</td>
<td>Vivek Polshettiwar</td>
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</table>

### Biology

**Autumn 2017 (August 17 - January 18)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>Genetics</td>
<td>B. J. Rao, Shobona Sharma, Shubha Tole, Krishnan Ray, Roop Malik, Maithreyi Narasimha, Ullas Kolthar, Srinelaja Nair, Mahendra Sonawane, Mitbilesh Mishra, Shamik Dasgupta, Vidita Vaidya</td>
</tr>
<tr>
<td>Cell and Developmental Biology</td>
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<tr>
<td>Molecular Biology</td>
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<tr>
<td>Biochemistry</td>
<td></td>
</tr>
<tr>
<td>Techniques in Modern Biology</td>
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<tr>
<td>Basic Neuroscience</td>
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**Spring 2018 (March 2018 - July 2018)**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Cortical Development: Cells and circuits</td>
<td>Shubha Tole</td>
</tr>
<tr>
<td>Cortical Development: Intrinsic and extrinsic factors</td>
<td>Shubha Tole</td>
</tr>
<tr>
<td>Scientific Reading, Writing, and Presentation</td>
<td>Shubha Tole</td>
</tr>
</tbody>
</table>
Advanced Genetics
Advanced Developmental Biology
Advanced Molecular Physiology
Advanced Cell Biology

Mithilesh Mishra
Sreelaja Nair
Ullas Kalthur
Maitreyi Narasimha

Computer and System Sciences

Autumn 2017 (August 17-December 17): Core Courses

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algorithms</td>
<td>Umang Bhaskar</td>
</tr>
<tr>
<td>Analysis of Boolean Functions</td>
<td>P. Harsha</td>
</tr>
<tr>
<td>High Dimensional Geometry</td>
<td>H. Narayanan</td>
</tr>
<tr>
<td>Automata</td>
<td>P. Pandya</td>
</tr>
<tr>
<td>Probability</td>
<td>V. Prabhakaran</td>
</tr>
<tr>
<td>Mathematical Foundations for Computer Science</td>
<td>J. Radhakrishnan</td>
</tr>
<tr>
<td>Topics in Interactive proof Checking</td>
<td>N. Raja</td>
</tr>
<tr>
<td>Algebraic Circuit Complexity</td>
<td>R. Saptharishi</td>
</tr>
<tr>
<td>Analysis</td>
<td>P. G. D. Sen</td>
</tr>
<tr>
<td>Analysis of Markov Chains</td>
<td>P. Srivastava</td>
</tr>
<tr>
<td>Learning Theory</td>
<td>R. Vaze</td>
</tr>
<tr>
<td>Game Theory (Reading Course)</td>
<td>U. Bhaskar</td>
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</tbody>
</table>

Spring 2018 (January 18 - May 18)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Automata</td>
<td>P. K. Pandya</td>
</tr>
<tr>
<td>Advanced Probability Including Large Deviations</td>
<td>S. K. Juneja</td>
</tr>
<tr>
<td>and Stochastic Calculus</td>
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</tr>
<tr>
<td>Combined Optimization</td>
<td>Umang Bhaskar and T. Kavita</td>
</tr>
<tr>
<td>Computational Complexity</td>
<td>P. Harsha</td>
</tr>
<tr>
<td>Concrete Lower Bounds</td>
<td>Arkadev Chattopadhyay</td>
</tr>
<tr>
<td>Information Theory</td>
<td>V. M. Prabhakaran</td>
</tr>
<tr>
<td>Numerical Algorithms</td>
<td>A. Srivastava</td>
</tr>
<tr>
<td>Quantum Computation and Information</td>
<td>J. Radhakrishnan</td>
</tr>
<tr>
<td>Probabilistically Checkable Proofs (Reading Course)</td>
<td>P. Harsha</td>
</tr>
<tr>
<td>Privacy (Reading Course)</td>
<td>V. Prabhakaran</td>
</tr>
<tr>
<td>Ideals, Varieties and Algorithms (Reading Course)</td>
<td>R. Saptharishi</td>
</tr>
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</table>

ICTS Graduate School

August 17-December 17

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Minimal surfaces</td>
<td>Rukmini Dey</td>
</tr>
<tr>
<td>Statistical Physics 2</td>
<td>Anupam Kundu</td>
</tr>
<tr>
<td>Advanced Quantum Mechanics</td>
<td>Suvrat Raju</td>
</tr>
<tr>
<td>Classical Mechanics</td>
<td>Samriddhi Sankar Ray</td>
</tr>
<tr>
<td>Introduction to partial differential equations</td>
<td>Vishal Vasan</td>
</tr>
<tr>
<td>Nonequilibrium statistical physics (Reading course)</td>
<td>Abhishek Dhar</td>
</tr>
<tr>
<td>Classical Gauge Theory (Reading course)</td>
<td>R. Loganayagam</td>
</tr>
</tbody>
</table>

January 18 - May 18

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical methods for physics and astrophysics</td>
<td>P. Ajith</td>
</tr>
<tr>
<td>Statistical and quantum field theory</td>
<td>Subhro Bhattacharjee</td>
</tr>
<tr>
<td>Condensed Matter Physics - Interacting Systems</td>
<td>Chandan Dasgupta</td>
</tr>
<tr>
<td>Advanced Lab</td>
<td>Rama Gorindanikan</td>
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<tr>
<td>Classical Electrodynamics</td>
<td>R. Loganayagam</td>
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</table>
### NCBS Graduate School

**August Term – 2017**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Research Methodology A: Synthesizing literature</td>
<td>Deepa Agashe, Anjana Badrinarayanan</td>
</tr>
<tr>
<td>Basic Ecology</td>
<td>Deepa Agashe</td>
</tr>
<tr>
<td>Neuro2: Circuits and systems</td>
<td>Vatsala Thirumalai and Sanjay Sane</td>
</tr>
<tr>
<td>Workshop on Advanced data analysis in R</td>
<td>R. Srivatsan, IBAB, Bangalore</td>
</tr>
<tr>
<td>Comprehending Development</td>
<td>Tina Mukherjee, Raj Ladher and Ramkumar Sambasivan</td>
</tr>
<tr>
<td>Information Theory</td>
<td>Mukund Thattai</td>
</tr>
<tr>
<td>Basic Biology A</td>
<td>Sanjay P Sane, Shachi S Gosavi, Mukund Thattai,</td>
</tr>
<tr>
<td></td>
<td>Dasaradhi Palakodeti</td>
</tr>
<tr>
<td>Basic Biology B</td>
<td>Sanjay P Sane, Deepa Agashe, Axel Brockmann, Tina</td>
</tr>
<tr>
<td></td>
<td>Mukherjee, Shannon B Olsson</td>
</tr>
<tr>
<td>Genetics and Molecular Biology</td>
<td>Dimple Notani, Dasaradhi Palakodeti, Gaiti Hasan,</td>
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<tr>
<td></td>
<td>Arwin Seshasayee, Anjana Badrinarayanan</td>
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<tr>
<td>Discovery to public health</td>
<td>Sudhir Krishna, Reety Arra (NCBS); S. Prashantb and</td>
</tr>
<tr>
<td></td>
<td>Upendra Bojani (Institute of Public Health)</td>
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**January Term – 2018**

<table>
<thead>
<tr>
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<th>Instructor(s)</th>
</tr>
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<tbody>
<tr>
<td>Chemical Ecology</td>
<td>Radhika Venkatesan</td>
</tr>
<tr>
<td>How to Write and Publish Papers</td>
<td>Krushnamegh Kunte</td>
</tr>
<tr>
<td>Evolution and Population Genetics</td>
<td>Uma Ramakrishnan</td>
</tr>
<tr>
<td>Neuro1: Cells, computation, and synapses</td>
<td>Upinder Bhalla and Sumantra Chattarji</td>
</tr>
<tr>
<td>Stem cells and Disease</td>
<td>Shravantri Rampilli and Dhandaparry Perundurai</td>
</tr>
<tr>
<td>Advanced topics in non-linear dynamics</td>
<td>Sandeep Krishna</td>
</tr>
<tr>
<td>Current methods in Biology</td>
<td>Akash Gulyani and Arati Ramesh</td>
</tr>
<tr>
<td>Advanced Bioinformatics</td>
<td>R. Sowdhamini</td>
</tr>
<tr>
<td>Cell Biology</td>
<td>Satyajit Mayor, Srikala Raghavan, Arjun Gaba, Minbaj</td>
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<tr>
<td></td>
<td>Sirajuddin, Colin Jamora, Jyotsna Dhanve</td>
</tr>
<tr>
<td>RNA Biology</td>
<td>Ravi Muddasbetty, P.V. Shivaprasad</td>
</tr>
<tr>
<td>Genome Biology</td>
<td>Dasaradhi Palakodeti, Aswin Seshasayee</td>
</tr>
<tr>
<td>Molecular Genetics and Cell Biology of Bacteria</td>
<td>Arwin Seshasayee, Anjana Badrinarayanan</td>
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### NCRA-IUCAA Graduate School

**Mar-Apr 2018**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>Advanced Radio Astronomy</td>
<td>Chengalur, Jayaram</td>
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### TCIS Graduate School

**Physics**

**Jan-Apr 2017 Semester**

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid State Physics – I / Condensed Matter Physics</td>
<td>Subodh R. Shenoy</td>
</tr>
<tr>
<td>Quantum Mechanics – II</td>
<td>N. D. Hari Das</td>
</tr>
<tr>
<td>Numerical Methods – II</td>
<td>Smarajit Karmakar and Prasad Perlekar</td>
</tr>
</tbody>
</table>
Physics & Chemistry of materials: Bulk to Nano  
Modern Topics in Statistical Mechanics  
Atomic & Molecular Physics  
Experimental Methods  

T.N. Narayanan and K.V. Raman  
Mustansir Barma and Surajit Sengupta  
M. Krishnamurthy  
T.N. Narayanan and G Rajalakshmi  

Aug-Nov 2017 Semester  

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Quantum Mechanics - I</td>
<td>Raghunathan Ramakrishnan</td>
</tr>
<tr>
<td>Classical Electrodynamics - I</td>
<td>N.D. Hari Das</td>
</tr>
<tr>
<td>Statistical Mechanics - I</td>
<td>Jagannath Mondal</td>
</tr>
<tr>
<td>Experimental Methods</td>
<td>Prasad Perlekar</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>T.N. Narayanan and G Rajalakshmi</td>
</tr>
<tr>
<td>Mathematical Methods</td>
<td>P.K. Madhu</td>
</tr>
<tr>
<td>Statistical Mechanics - II</td>
<td>Sumanjit Karmakar</td>
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</table>

Chemistry  
Jan-Apr 2017 Semester  

<table>
<thead>
<tr>
<th>Course Name</th>
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<tbody>
<tr>
<td>Advanced Mathematical Methods</td>
<td>P.K. Madhu and Raghunathan Ramakrishnan</td>
</tr>
<tr>
<td>Molecular and Nonlinear dynamics</td>
<td>Jagannath Mondal and Pushpita Ghosh</td>
</tr>
<tr>
<td>Advanced Topics in Organic &amp; Inorganic Chemistry</td>
<td>Anukul Jana</td>
</tr>
<tr>
<td>Solid State NMR</td>
<td>Vipin Agarwal</td>
</tr>
<tr>
<td>Principles of NMR Spectroscopy</td>
<td>K.V.R. Chary</td>
</tr>
<tr>
<td>Electronic structure Theories of Matter</td>
<td>Raghunathan Ramakrishnan</td>
</tr>
<tr>
<td>Biophysics</td>
<td>Pramod Vallurupalli and Kanchan Garai</td>
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Aug-Nov 2017 Semester  

<table>
<thead>
<tr>
<th>Course Name</th>
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<tbody>
<tr>
<td>Quantum Mechanics - I</td>
<td>Raghunathan Ramakrishnan</td>
</tr>
<tr>
<td>Organic &amp; Inorganic Chemistry</td>
<td>Anukul Jana and Kalyaneswar Mandal</td>
</tr>
<tr>
<td>Statistical Mechanics - I</td>
<td>Jagannath Mondal</td>
</tr>
<tr>
<td>Principles of NMR Spectroscopy</td>
<td>P.K. Madhu and Vipin Agarwal</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Subodh R. Shenoy</td>
</tr>
<tr>
<td>Mathematical Methods</td>
<td>P.K. Madhu</td>
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</tbody>
</table>

Biology  
Jan-Apr 2017 Semester  

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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</thead>
<tbody>
<tr>
<td>Biological Thermodynamics</td>
<td>Tamal Das</td>
</tr>
<tr>
<td>Biophysics</td>
<td>Pramod Vallurupalli and Kanchan Garai</td>
</tr>
</tbody>
</table>

Aug-Nov 2017 Semester  

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Genetics</td>
<td>Manish Jaiswal</td>
</tr>
<tr>
<td>MechanoBiology</td>
<td>Tamal Das</td>
</tr>
<tr>
<td>Cell physiology and Cell signaling</td>
<td>G. Velumurugan</td>
</tr>
<tr>
<td>Basic Cell Biology</td>
<td>Aprotim Magunder</td>
</tr>
<tr>
<td>Research Methodology</td>
<td>Subodh R. Shenoy</td>
</tr>
</tbody>
</table>
HBCSE Graduate School

**Short Course** (June-July 2017)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic writing</td>
<td>Devasmita Chakraverty, Assistant Professor of science education at Washington State University Spokane</td>
</tr>
</tbody>
</table>

**Summer Elective Courses** (July-August 2017)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perspectives on socio-scientific issues education: Reading course</td>
<td>Sugra Chunawala and Aswathy Ravendran</td>
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</table>

**Fall Core Courses** (August - December 2017)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>History of Science</td>
<td>G. Nagarjuna</td>
</tr>
<tr>
<td>Cognition, Cognitive development and Learning</td>
<td>Sanjay Chandrasekharan</td>
</tr>
<tr>
<td>Introduction to Science &amp; Mathematics</td>
<td>Aniket Suls, Rohini Karandikar and Aaloka Kanber</td>
</tr>
<tr>
<td>Methods of Science &amp; Mathematics Education Research</td>
<td>Sonali Raje</td>
</tr>
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</table>

**Foundational Elective Courses / Elective Courses** (August - December 2017)

<table>
<thead>
<tr>
<th>Course Name</th>
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<tbody>
<tr>
<td>Seeing education in its social context</td>
<td>Amman Madan</td>
</tr>
<tr>
<td>Seminar course on research in multiplicative thinking and algebra learning</td>
<td>K. Subramaniam and Shweta Naik</td>
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**Second Year Courses** (August - December 2017): Core Courses

<table>
<thead>
<tr>
<th>Course Name</th>
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<tbody>
<tr>
<td>Teaching practice and school internship / design of learning resource Part II</td>
<td>Shubhangi Bhide and Shweta Naik</td>
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<tr>
<td>Advanced course on methods of science &amp; mathematics education research</td>
<td>Sonali Raje and Sugra Chunawala</td>
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**Spring Core Courses** (January-April 2018)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
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<tbody>
<tr>
<td>Advanced topics in research methods in education</td>
<td>Mashood K. K. and Sugra Chunawala</td>
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<tr>
<td>Teaching practice and school internship / design of learning resource Part I</td>
<td>Aaloka Kanber and Adithi Muralidhar</td>
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<tr>
<td>Summer Course on Teaching practice and school internship / design of learning resources</td>
<td>Aaloka Kanber and Adithi Muralidhar</td>
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**Foundational Elective Courses** (January-April 2018)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trends in philosophy of education</td>
<td>Gagan Deep Kaur</td>
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</table>

**Elective Course** (January-April 2018)

<table>
<thead>
<tr>
<th>Course Name</th>
<th>Instructor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to life science education</td>
<td>Deepti Gupta and Rohini Karandikar</td>
</tr>
<tr>
<td>Student</td>
<td>Supervisor</td>
</tr>
<tr>
<td>----------------------</td>
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</tr>
<tr>
<td>Deepshikha Verma</td>
<td>K.V.R. Chary</td>
</tr>
<tr>
<td>Carina B. Maliakkal</td>
<td>Arnab Bhattacharya</td>
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<tr>
<td>Bhamidi Sai Somanjana Sreedar</td>
<td>Amalendu Krishna</td>
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<tr>
<td>Varun Varma</td>
<td>Mahesh Sankaran</td>
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<tr>
<td>Sabareesan A. T.</td>
<td>Jayanth B. Udgaonkar</td>
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<tr>
<td>Somya Mani</td>
<td>Makund Thattai</td>
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<tr>
<td>Prabhat Kumar Tiwari</td>
<td>VijayRaghavan K.</td>
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<tr>
<td>Sramana Kundu</td>
<td>E. Krishnakumar/Vaitaar Prabhudesai</td>
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<tr>
<td>Anindita Sarkar</td>
<td>Ankona Datta</td>
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<tr>
<td>Sarat B. Moka</td>
<td>Sandeep Juneja</td>
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<tr>
<td>Sanat Ghosh</td>
<td>Sanjeet Wategaonkar</td>
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<tr>
<td>Anupama H. L.</td>
<td>Satyajit Mayor</td>
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<tr>
<td>Aalap Bhalchandra Mogre</td>
<td>Ashwin S. N. Sehatajye</td>
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<td>Arideep Saha</td>
<td>Indranil Biswas</td>
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<tr>
<td>Chandan Ghosh</td>
<td>Vandana Nanal</td>
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<tr>
<td>Ravichandran S</td>
<td>Rama Govindarajan</td>
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<tr>
<td>Madhuresh</td>
<td>Sreekar Vadatalamani/Amit Apte</td>
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<tr>
<td>Mahita Jarapu</td>
<td>Sovdilamoni R.</td>
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<td>Lovy Singhal</td>
<td>Anish Ghosh</td>
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<td>Rakesh Ratnakar</td>
<td>V’ Srinivas</td>
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<td>Ajith Padyana</td>
<td>Achanta Venugopal</td>
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<tr>
<td>Ravishankar</td>
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<tr>
<td>Swagatha Ghosh</td>
<td>Satyajit Mayor/S. Ramaswamy</td>
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<tr>
<td>Samsuzzoha Mondal</td>
<td>Ankona Datta</td>
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<tr>
<td>Dwaipayan D. Gupta</td>
<td>Sbyamalava Marzumdar</td>
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<tr>
<td>Aswathy Raveendran</td>
<td>Supra Chitawala</td>
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<td>Vijaya Lakshmi K.</td>
<td>Jyothishman Dasgupta</td>
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<tr>
<td>Bappadiyana Chandra</td>
<td>Sudipta Maiti/P. K. Madhu</td>
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<tr>
<td>Palas Roy</td>
<td>Jyothishman Dasgupta</td>
</tr>
<tr>
<td>Student</td>
<td>Supervisor</td>
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<tr>
<td>----------------------</td>
<td>-----------------------------</td>
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<tr>
<td>Anveshna Srivastava</td>
<td>Sanjay Chandrasekharan</td>
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<tr>
<td>Sharath K Jose</td>
<td>Rama Govindarajan</td>
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<tr>
<td>Minal Jaggat</td>
<td>Vidita Vaidya</td>
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<tr>
<td>Bibhuprasad Mahakud</td>
<td>Gagan B. Mohanty</td>
</tr>
<tr>
<td>Jacky Kumar</td>
<td>Manoranjan Guchait</td>
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<tr>
<td>Bipan Kumar Deb</td>
<td>Gauti Hasan</td>
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<tr>
<td>Farah Haque</td>
<td>R. Sourav Chatterji</td>
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<tr>
<td>Neha Nandwani</td>
<td>Jayant Udgaonkar</td>
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<tr>
<td>Kamalesh Kumar</td>
<td>Shobhana Sharma/Raghu Padiyajj</td>
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<tr>
<td>Mandira Mondal</td>
<td>Vijaylaxmi Triwedi</td>
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<tr>
<td>Chaitali Khan</td>
<td>B. J. Rao</td>
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<tr>
<td>Varghese Babu</td>
<td>Tarig Aziz/Gagan B. Mohanty</td>
</tr>
<tr>
<td>Rini Ganguly</td>
<td>Pratap Raychaudhari</td>
</tr>
<tr>
<td>Rama Reddy Goluguri</td>
<td>Jayant B. Udgaonkar</td>
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</table>

### Integrated M.Sc.-Ph.D. Theses

<table>
<thead>
<tr>
<th>Student</th>
<th>Supervisor</th>
<th>Thesis Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aditya J.N.H.S.</td>
<td>Nisim Kanekar</td>
<td>Cold gas in high redshift galaxies</td>
</tr>
<tr>
<td>Krishnendu Gope</td>
<td>V Prabhudesai</td>
<td>Structure and Dynamics of Excited States of Molecular Anions</td>
</tr>
<tr>
<td>Deep Ray</td>
<td>Prawen Chandrahekaranappa/Siddharth Mishra (ETH Zurich)</td>
<td>Entropy-stable finite difference and finite volume schemes for compressible flows</td>
</tr>
<tr>
<td>Radhika Sudhir Joshi</td>
<td>M. M. Panicker</td>
<td>Understanding the role of 5-HT2A in the behavioral and biochemical effects of antipsychotics</td>
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<tr>
<td>Farhana Yashin</td>
<td>Sumanta Chattarji</td>
<td>Characterisation and reversal of the delayed synaptic effects of acute stress in the amygdala</td>
</tr>
<tr>
<td>Shubhadeep Biswas</td>
<td>Lokesh Trivedi</td>
<td>Study of multi-electronic systems under heavy ion impact</td>
</tr>
<tr>
<td>Rohit Kumar Mishra</td>
<td>Venkateswaran P. Krishnan</td>
<td>Some uniqueness results in tensor tomography</td>
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<tr>
<td>Sayani Biswas</td>
<td>Rudrajit Palit</td>
<td>Excitation modes in spherical and transitional nuclei in A~130 mass region</td>
</tr>
<tr>
<td>Arijit Ganguly</td>
<td>Anish Ghosh</td>
<td>Problems in Diophantine approximation and dynamical systems</td>
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<tr>
<td>Sombuddha Bhattacharya</td>
<td>Venkateswaran P. Krishnan</td>
<td>Inverse Problems on Riemannian manifolds</td>
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<tr>
<td>Sameer Grover</td>
<td>Mandar Deshmukh</td>
<td>Optoelectronic properties and photoresponse of graphene</td>
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<tr>
<td>Sagnik Mukhopadhyay</td>
<td>Arkadev Chatterjee</td>
<td>Communication Complexity Amplification by Function Composition</td>
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<tr>
<td>Shlesha Rajesh Richhariya</td>
<td>Gauti Hasan</td>
<td>Investigating the role of store-operated calcium entry in neurons; Gene expression and physiological functions</td>
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<tr>
<td>Prakash Gaikwad</td>
<td>Tirthankar Ray Chunibar</td>
<td>Efficient hydrodynamical simulations of the intergalactic medium and parameter estimation</td>
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<td>Soureec Mitra</td>
<td>Tarig Aziz/Gagan B. Mohanty</td>
<td>Measurement of single top t-channel production cross-section and top quark mass in single top events using CMS detector</td>
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<tr>
<td>Debijyoti Bardhan</td>
<td>Sreerup Raychaudhari</td>
<td>Probing New Physics in Weak Decays and Flavour Changing Processes</td>
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<tr>
<td>Swagata Dey</td>
<td>Krishnan Ray</td>
<td>Modalities of Kinesin-2 mediated axonal transport in Drosophila melanogaster and their implications</td>
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<tr>
<td>Deepesh Kumar Data</td>
<td>Vinod, M. Prabhakaran</td>
<td>Computational Complexity and Characterization Results in Secure Computation</td>
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M. Sc. Theses

<table>
<thead>
<tr>
<th>Student</th>
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<tbody>
<tr>
<td>Chandan Kumar Pandey</td>
<td>Malesh Sankaran</td>
<td>Nutrient addition and lack of grazing reduce establishment of leguminous savanna tree seedling</td>
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<td>Rahul Jain</td>
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<td>Based on Coursework</td>
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<tr>
<td>Anasuya Moitra</td>
<td>Goutam Janori</td>
<td>Functional Significance of a parasite specific pentapeptide insert in Plasmodium spp. Enolase</td>
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<tr>
<td>Karen Grace Soans</td>
<td>Maitrey Naraasima</td>
<td>The Role of Delta in patterning cell delamination during Drosophila Closure</td>
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<tr>
<td>Ishita Sarkar</td>
<td>Shobana Sharma</td>
<td>Investigating the long term effects of mild malaria on stress susceptibility using juvenile and adult murine model</td>
</tr>
<tr>
<td>Sonia Ray</td>
<td>B. J. Rao</td>
<td>The Role of ATM, the Master Regulator of DNA damage Response in Tissue Homeostasis Functions of Drosophila</td>
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<tr>
<td>Sanya Aich</td>
<td>Mithilak Mishra</td>
<td>Role of Nuclear- cytoplasmic transport in Cytokinesis</td>
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<tr>
<td>Zeba Sohel Khatri</td>
<td>Shubha Tole</td>
<td>Transcriptional regulation of neuronal subtype identity in the mammalian cortex</td>
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<tr>
<td>Sweta Parik</td>
<td>Ullas Kolthar</td>
<td>Investigating the role of Drosophila Sirt4 in the regulation of mitochondrial function and organismal physiology</td>
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<tr>
<td>Ashwin I. D’ souza</td>
<td>Roop Mallik</td>
<td>Understanding the role of dynein-dynactin complex in regulating bidirectional motion of phagosomes</td>
</tr>
<tr>
<td>Anusheela Chatterjee</td>
<td>Sandhya Kaushika</td>
<td>Regulation of mitochondrial density in neurons</td>
</tr>
<tr>
<td>Dipri Rai</td>
<td>Krishnan Ray</td>
<td>Kinesis-2 role in regulating synapse assembly in the developing central nervous system of Drosophila</td>
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<tr>
<td>Natasha Steffi Lewis</td>
<td>Mahendra Sonawane</td>
<td>Characterizing the response of the Zebrafish Embryonic epidermis to mechanical stretch using a novel paradigm</td>
</tr>
<tr>
<td>Keerthan Subramanian</td>
<td>---</td>
<td>M.Sc. Project(Refuting local hidden variable theories without recourse to non-locality</td>
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Projects under the National Initiative in Undergraduate Science, HBCSE

Chemistry
1. Deepak Kumar (Hansraj College, University of Delhi); Role of 1,3-diketone in synthesis of heterocycles using cerium chloride as green catalyst (Mentors: G. Shridhar, V. K. Menon College, Mumbai, L. Ravishankar, KET Vaze College, Mumbai and S. Ladage, HBCSE, Mumbai)
2. Anjali Jayachandran (UM DAE CBS, Mumbai); Pedagogy in Quantum Chemistry (Mentors: S. Ladage, HBCSE, Mumbai and A. Kumar, formerly HBCSE, Mumbai)
3. Adilil Kaber K (IISER Bhopal); Effect of container material on water quality parameters (Mentor: A. Gupta, HBCSE, Mumbai)

Physics
1. Kshitij Patil (KJSSC & KJSCE, Mumbai); Astereoseismology: Analysis of the solar-type star ‘kic008006161’ (Mentor: A. Mazumdar, HBCSE, Mumbai)
2. Anwesh Bhattacharya (IISER, Pune); Astereoseismology: Analysis of the solar-type star ‘kic008006161’ (Mentor: A. Mazumdar, HBCSE, Mumbai)
3. Ankur Chauhan (Hansraj College, Delhi); Kinematics of slow and fast CMEs (Mentors: D. Banerjee, IIA, Bangalore and A. Mazumdar, HBCSE, Mumbai)
4. Mudit Chauhe (PDPM Indian Institute of Technology Design & Manufacturing, Jabalpur); Investigation of methods to achieve surface Plasmon resonance in visible frequencies of the Electromagnetic spectrum in Aluminium (Mentors: M. Roy, PDPM Indian Institute of Technology Design & Manufacturing, Jabalpur and P. Pathak, HBCSE, Mumbai)
The Science Popularization and Public Outreach Committee at the TIFR Colaba campus coordinates several initiatives for the larger public to engage with research at the institute, with a range of activities in various formats, both in- and off-campus, and for small and large audiences, around the year. Several programmes highlight exciting new developments in science and technology, with a special emphasis on showcasing research done at TIFR. A major focus is to reach out to school/college students and teachers, especially in under-served communities, and inspire young students to pursue careers in science.

Our annual open house programme, “Frontiers of Science”, provides a unique opportunity for 9th/10th standard students and teachers from selected schools in and around Mumbai to visit the institute, for an exciting day of informative lectures, engaging science demonstrations and lab visits. In 2017, over 40 laboratories and facilities at TIFR welcomed more than 1,700 visitors from more than 100 schools. TIFR also has a large open house around National Science Day (Feb 28th) where more than 2,000 people visit the campus for a “science mela”, lecture-demonstrations and lab visits.

Our flagship Science Café-style initiative in Mumbai called “Chai and Why?” has been running without a break every two weeks on alternate Sundays since 2009. In the almost 250 sessions held so far, researchers from TIFR have engaged the public with informal and accessible discussions of science outside the traditional academic setting. An amazingly diverse range of topics across the sciences, and their connections to the world we live in, have firmly established “Chai and Why?” on Mumbai’s science calendar. It has also pushed the boundaries of a standard Science Café with unique “Summer Specials” for children (of all ages) with hands-on experiments, festival specific sessions on Holi and Diwali etc. Chai and Why? also pioneered the use of social media for science outreach in India, developing an active community on Facebook with average weekly visits by around 7,000 people. We plan to extend the sessions to live webcast, to reach out to a wider audience. Many ideas developed for Chai and Why? sessions have been extended to develop interactive science-demos that are popular at schools, with the local Marathi language versions enthusiastically appreciated in rural Maharashtra. These demos, along with night-sky observation sessions, have helped organize a vibrant rural outreach programme, reaching out to nearly 20,000 students every year. The team has also developed several low-cost/no-cost experiments designed for large audiences, taking into account minimal access to demo equipment/infrastructure.

The outreach team organizes periodic public lectures on different aspects of science and technology by TIFR faculty and distinguished visitors to the institute. These are held not only at TIFR, but at various colleges across the city as well. The outreach team has also put up stalls showcasing TIFR research at various exhibitions, such as IIT-Bombay’s Techfest, Nehru Science Centre, and the Giant Metrewave Radio Telescope facility’s Science Day programme. The importance of fundamental research is conveyed through novel interactive exhibits, such as live tracks of cosmic ray particles going through arrays of detectors, the behavior of temperature-sensitive mutant fruit flies, and geometric figures from soap films.

Chai and Why?

Manoj Purveshkar, How do (exo)planetary systems form? Prithvi House, Apr 2, 2017
Deborah Dutta, From farm to plate: A thought for food. Ruparel College, Apr 16, 2017
Mayank Narang and team, Build your own galaxy!, Alexandra School, Apr 30, 2017
Ranjan Das, Herbal, Natural, Organic, Chemical free?, Prithvi Cafe, May 7, 2017
Zeba Khatri, A brief history of the brain. Ruparel College, May 21, 2017
Most TIFR centres also have their own active outreach programmes. Some of the major ones are detailed below.

**The National Centre for Biological Sciences (NCBS), Bengaluru**

NCBS has a very vibrant outreach program in life science research, with two main threads. One is focused inwards, seeking to develop science communication capabilities at all levels at the centre. Key activities in this thread include workshops and talks on campus, by leading science communicators from India and abroad, such as Dr. Meenakshi Prabhune (scientist-turned writer), Sir Prof. David Speigelhalter (Cambridge University), Mr. Kollegala Sharma (scientist communicator), Dr. Adria Leboeuf (Weizmann Institute of Science), Samuel Lagier (University of Geneva) , and Doug Sipp (RIKEN Institute) .

The second thread engages with the public. Key events in this thread include The Jigyasa Project (an initiative for educational talks in Tamil and Kannada, and soon Hindi), Science and the City (science at apartment complexes and informal settings such as cafes; this event was a finalist at Falling Walls Berlin 2018 symposium, part of the Berlin Science Week), Swissnex Science Comm (a day-long conference around the theme of “scientainment” -- science + entertainment -- featuring experts from Switzerland and India), Artist in Residence exhibition (by NCBS-TIFR's artist-in-residence, Dhara Mehrotra) and the Open Science Day (more than 1000 people visited the centre in 2018).

**Homi Bhabha Centre for Science Education (HBCSE), Mumbai**

HBCSE’s outreach seeks to develop deeper engagements with science at the school level, particularly through talent nurture and teacher education programs. High impact programs include Vigyan Pratibha (science talent nurture programme for Class 8-10 students in Kendriya Vidyalayas, Navodaya Vidyalayas, and Atomic Energy Central Schools), CUBE (a novel nation-wide project to learn undergraduate biology collaboratively, using inexpensive equipment, simple model organisms and hubs based in colleges) and National Science Day (more than 2000 students and teachers visited this year). The centre also runs student workshops (more than 30 this year) and a very active visitor program (more than 600 visitors this year).

**National Centre for Radio Astronomy (NCRA), Pune**

The Giant Metrewave Radio Telescope (GMRT, Pune) observatory of NCRA organizes one of the largest science exhibitions in the country around National
Science Day, drawing crowds of about 20000 people over two days, involving more than 600 school and college projects, interactive experiments, talks, workshops and movie screenings. Apart from this, NCRA seeks to help increase Astronomy awareness and literacy around Junnar district, and hosts school and college groups who wish to see the telescopes in Pune and Ooty.

The International Centre for Theoretical Sciences (ICTS), Bengaluru

ICTS organises frequent Public Lectures (by eminent scientists from India and abroad), the Einstein Lectures series (where schools, colleges and other organizations can request to organize a lecture anywhere in India, covering a wide spectrum of topics) and Kaapi with Kuriosity (a monthly public lecture series, in collaboration with the Jawaharlal Nehru Planetarium and other educational institutions in Bengaluru).

TIFR Centre for Interdisciplinary Sciences (TCIS), Hyderabad

TCIS organises Deep Learning, an outreach initiative with schools of the Telangana Social Welfare Residential Educational Institutions Society, to support meaningful, laboratory-based science learning. As part of the initiative, low-cost paper microscopes called “Foldscopes” were introduced in a few schools recently on a pilot basis. TCIS also runs the Meet a Scientist program, conducted in face-to-face mode in local schools, and in distance mode in remote schools. Apart from popular talks on specialised areas, this program is devoted to addressing students’ questions.

Popular Science Lectures

H. M. Antia
2. Indian Space Program and AstroSat. BITS Pilani, GOA campus, September 10, 2017
3. Introduction to Numerical Techniques. BITS Pilani, GOA campus, September 10, 2017
4. Indian Space Program and AstroSat. INSPIRE camp at Dayanand Science College Latur, October 14, 2017
5. The Sun. INSPIRE camp, Dayanand Science College Latur, October 15, 2017
6. Probing the Solar Atmosphere and Interior. INSPIRE camp, Ravishankar University, Raipur, Dec 30, 2017

C. S. Aravinda

A tiling tale: that took 100 years to complete. Public talk at the Mathematics Day 2018, IISER Pune, 10 March 2018

Anjana Badrinarayan

Popular science lecture to the science enthusiast group ‘Hitchhicker’s Galaxy’, Bangalore

Arnab Bhattacharya
1. Why bother about basic research. Sophia College, Mumbai, Feb. 28, 2018, and also at Institute of Chemical Technology, Mumbai, Sep. 21, 2017
2. Light, Colour, Action. Exciting Science Group, IISER Pune, Smt Indrani Balan Science Activity Centre, Pune, Feb. 4, 2018
3. Engaging the public with science: one cup at a time! Humboldt Colloquium, “Germany and India – Partners in Education and Research”, Bangalore, Nov. 24, 2017, also at Euraxess Science Communication Workshop, Anna University, Chennai, Nov. 11, 2017

Ankona Datta
1. How to become a Scientist? Frontiers of Science, November 2017, TIFR, Mumbai
2. Imaging the Chemistry of Life, Rendezvous, CEBS, September 2017, Mumbai
3. Seeing the Chemistry of Life, Junoon Mumbai Local, April 2017, Kitab Khana, Mumbai
4. Spy Molecules, Gondwana University, February 2017, Gadchiroli, India

Amol Dighe
1. Going underground to look at the sky. Science Forum talk (Marathi), Kankavli, Jan 2018
2. The invisible neutrinos and how they make the sky visible. Public Lecture, MNIT Jaipur, Nov 2017
4. Those invisible neutrinos and their astroparticle physics, Tea-time talk, VSRP program, TIFR, Jul 2017

D. Dutta
From farm to plate: Thought for food. Chai and Why session, Ruparel College, April 16, 2017

Rajiv Gavai
Sanshodhan: Ek Wyavasay, Chhand Wa Karkird. Silver Jubilee Function of IES Katrap Vidyalaya, Badlapur, 1 December 2017
3. The Coordination of Affairs. Syntalk Soundcloud discussion

Gautam Mandal
Career Conversations. Naval Children's School, Mumbai, July 2017

Aprotim Mazumder
Invited panelist, Precision 2017, a first undergraduate research meeting of Presidency University, Kolkata

Mithilesh Mishra
To divide or not to divide: Mechanism of cell division. Mumbai Local and Junoon, Dr. Bhau Daji Lal Museum, 13 August 2017

P. Nawale
1. Science popularization talk, for approximately 750 students of Class VII to IX, H. M. Pandit Vidyalay, Saphale, November 14, 2017
2. Science popularization talk, for approximately 300 students of Class VII to IX, Alibaug, January 27, 2018
3. Science activities for approximately 200 rural students of class V to VII, Talwada, Nashik, December 17, 2017
4. Science activities for approximately 200 rural students of class V to VII, Shivlegaon, Murbad, December 24, 2017
5. Science popularization talk, for around 36 students and 20 teachers, Shendurne, Shahpur, February 27, 2018
6. Sanwaad Vigyanacha. For around 200 students of Class IV and 4 teachers, Nuta Vidya Mandir, Mankhurd, March 14, 2018

Shannon Olsson
1. Endless forms most beautiful, Kaapi with Kuriosity, March 25, 2018
2. TEDx Chennai, March 11, 2018
3. TEDx Ashoka University, September 23, 2017

Vivek Polshettiwar
Nanocatalytic Solutions for Climate Change. Juhu Jagruti Hall, Mithibai College Building, Mumbai, 19 February 2018

S. S. Prabhu
1. Research Opportunities in Fundamental Science. Post-12th students in English and Marathi Vidyanan Parishad's student career guidance program, 23 April 2017
2. Waves. 9-10th Standard students (English Medium) of KatrapVidyalay, Badlapur, Mumbai, 23 August 2017
3. Taranga (Waves). 9-10th Standard students (Marathi Medium) of KatrapVidyalay at Badlapur, Mumbai, 22 September 2017

H. C. Pradhan
Planning a meaningful career in education. Annual Career Development Workshop for Students, Wilson College, Mumbai, April 11, 2017

Mansoj Parawankara
How do (exo)planetary systems form? Chai & Why, Prithvi Theatre, Mumbai, 2 April, 2017

Suvarn Raju
1. Black Holes and the Reversibility of Time. Einstein Lecture (National College), April 2017
2. Gravity and Quantum Information. Science Festival, July 2017

H. Raval and C. Navare
Twisting the untwisted: Mathematical space. Chai and Why? TIFR, Alexandra School, Mumbai, December 31, 2017

G. Rajalakshmi
Seeing and hearing Black Holes: opening a new era in Astronomy. ETHER Talks at Hyderabad Central University, 01 Nov 2017

Sneerup Raychaudhuri
1. From Nano to Atto: The Amazing World of Elementary Particles. 'Chai & Why', Prithvi Theatre, August 2017
2. The Final Frontier – the Story of Particle Physics. Workshop on Physics Learning Methodology, D. A. College, Kolkata, November 2017

Rajdeep Senarma
1. The Fascinating World of Ultracold Atoms. Presidency College Kolkata, January 2018
2. Irresistible Electrons. VSRP Lecture, TIFR students, July 2017

Aswin Sai Narain Seshasayee
1. Lecture at Science camp for mid-school teachers, Eklavya Foundation, Hoshangabad, June 2017
2. Lecture at DST-INSPIRE camp for high school students, Central University of Kerala, Kasaragod, December 2017

V. Sonawane
1. Food and nutrition: Pulses for sustainable development/Ekveera School, Charkop, Kandivali, July 16, 2017
2. Demonstration of school experiments for night school teachers of ‘Masoom’ NGO. Pioneer Hall, Matunga, Mumbai, February 14, 2018

Mukund Thatti
1. Bangalore Science Forum, 2017
2. REAP programme, Bangalore Planetarium, 2017

Shashi Thutupalli
From the Web of Life to the Universe. Bangalore summer
Mayank Vahia
1. The Big and Small of the Universe, Sawaal-Jawaab, TCIS, Hyderabad, February 3, 2018
2. Interaction with TSWREIS school students, TCIS, Hyderabad, February 2, 2018
3. Broadcast of Interaction with TSWREIS school students over T-SAT Nipuna. To reach out to remote TSWREIS schools in Telangana, February 3, 2018

Vidita Vaidya
1. The changing brain – a dialogue between your brain and environment. Teacher training Program, University of Mumbai, March 2017
2. Neuroplasticity: A dialogue between your brain and environment. IBRO workshop, NUS, Singapore, July 2017
5. Women in STEM – Plugging a Leaky Pipeline: An Indian Perspective. WLSTE, Kuwait, Oct 2017

Vishal Vaian
Dynamics of free surfaces. Lecture for J N Planetarium Summer Course, May 2017

Agarwal, Vipin
NMR Spectroscopy: Introduction and Perspectives. IEEE local chapter, Shri Ramdeobaba College of Engineering and Management, Nagpur, March, 2018

Popular Science Articles

P. Ajith

C. S. Aravinda
The Theorem of Pythagoras. January 2018 issue of Bhavana

Sumantra Chattarji
It’s all in your head. The Week, February 25, 2018

Rakmini Dey
The beautiful mathematics behind soap films: Minimal surfaces. Physics Academy of North East (PANE) Newsletter, 4 (1), 22

Aamol Dighe
Monthly series of articles in the column “vidnyaan-vaTa” (Directions in science) in the Marathi newspaper Maharashtra Times:
1. India-based Neutrino Observatory. Dec 2017
2. The merger of neutron stars. Nov 2017
4. Indian efforts to search for Dark Matter. Sep 2017
5. New charmed particles. Aug 2017
6. The dawn of quantum communication. Jun 2017
8. How muon is different from electron. Apr 2017

Bala Iyer

Gautam Mandal
Star Scientist, Scientist Star, Obituary of Stephen Hawking. Indian Express, March 15, 2018

Vinothkumar Kutti Ragunath
2017 Nobel Prize in chemistry – for cryoEM. Current Science, V113, 2017, P1493-1496

Suvrat Raju
Black Holes and the Reversibility of Time. ICTS Newsletter (2017)

Sreerup Raychaudhuri
Origins of Western Science in India. Commemorative Volume of Proiti, to Celebrate the 150th Birth Anniversary of Sister Nibedita, Kolkata, December 2017

T. P. Singh

R. Vartak
1. Mutrapindachya Chachanimaagil Shastra, Loksatta (Lok aaroga), September 7, 2017
2. Hridayvaaracha dhoka darshavnari Homocysteine chavhani, Loksatta (Lok aaroga), November 2, 2017
3. Raktatil Amylase: Amylase test, Loksatta (Lok aaroga), December 21, 2017
Rama Govindarajan
Moderator, Addressing the Gender Gap in Physics, ICTS-TIFR, March 2018

A. Gupta, B. Thube, H. Raval, H. Agarwal, K. Subramanian & V. Sonawane
Scientific experiments and demonstrations. 25th National Children’s Science Congress 2017, Ahmedabad, December 29-30, 2017

Bala Iyer
2. From Gravitational Wave Detection to Multi-Messenger Astronomy. Science Day, Vijaya College, Bangalore, February 2018
3. The detection of gravitational waves and the two body problem in general relativity – A personal recall. IOP, Bhubaneswar, January 2018
4. Deciphering the universe by gravitational wave observations. Silver Jubilee year of Samanta Chandrasekhar Amateur Astronomy Association (SCAAA), Bhubaneswar, January 2018
5. The fascinating story of gravitational wave detection: Physics Nobel 2017 and Beyond. VII All India Young Scientist Convention, Periyar University, Salem, December 2017
6. The fascinating story of gravitational wave detection: Physics Nobel 2017 and Beyond. MES Nobel Lectures 2017, MES College, Bangalore, November 2017
7. The fascinating story of gravitational wave detection: Physics Nobel 2017 and Beyond. Phi Delta Aplha, IISe, Bangalore, November 2017
8. The fascinating story of gravitational wave detection: Physics Nobel 2017 and Beyond. IIAR, Gandhinagar, November 2017
10. The fascinating story of gravitational wave detection: Physics Nobel 2017 and Beyond. ICTS-TIFR, Bangalore, October 2017
11. Introduction to General Relativity. JNP Summer Program, May 2017
12. The detection of Gravitational waves by LIGO. JNP Summer Program, May 2017
13. Introduction to General Relativity. One day seminar on Relativity, Gravity and Cosmology, Govt College, Mandya, April 2017
14. The detection of Gravitational waves by LIGO. One day seminar on Relativity, Gravity and cosmology, Govt. College, Mandya, April 2017

Manish Jaiswal
1. Science activities at TCIS. Dr. K. V. Rao Scientific Society and TCIS outreach committee, May 2017
2. Introductory lecture on science activities. Workshop on “Atoms to Amoeba”, organized by TCIS outreach committee at TCIS, Oct 2017

Ramadas, Jayashree
1. Feluda Science Mission. Aparna Sarовар, Hyderabad, September 2017
2. Learning with ‘Small Science’. Vivekananda School, Hyderabad, 12 February 2018

P. K. Joshi
Science popularization talk, for around 400 students, Vashind, February 28, 2018

P. K. Joshi and P. Nawale
Science practical demonstration for 200 students. S. P. S. Suvidyalaya School, Borivali (West), January 13, 2018

S. K. Jarmaja
Rendezvous session on Monte Carlo Methods in Finance. CEBS, Mumbai, January 16, 2018

Manas Kulkarni
Engineering exotic states of light and matter. The Einstein Public Lecture, M S Ramaiah Institute of Technology, Bangalore, September 2017

Krishnameh Kunte
Butterfly Stories: From Biology to Conservation. The Bangalore Science Forum at the National College, Basavanagudi, Bengaluru, 8 July 2017

Subhabrata Majumdar
1. Big Bang and our era of Cosmological Surveys. DTP-VSRP colloquium, June 2017
2. Isaac Newton, Rockets and Space Explorers. National Science Day Seminar, St Anne’s High School, February 28, 2018
3. Albert Einstein and His Mindboggling Theories of Our Amazing Universe. National Science Day Seminar, St Anne’s High School, February 28, 2018

Sadapta Maiti
1. Microscopy and Resolution. Centre for Excellence in Basic Sciences, Mumbai, March 29, 2018
2. Reinventing the Microscope: The Quest for Infinite resolution. Chai and Why, Feb. 4, 2018

Roop Mallick
1. Journal of Cell Biology -- People & Ideas
2. Junoon A Stage for Theatre – Watching Nanomachines at work
Radio and TV Programmes

Sumantra Chattarji
Are We As a Society Becoming Increasingly Violent, Guest Speaker on NDTV, May 29, 2017

Ankona Datta
1. Radio Interview, Radio One, April 2017
2. Radio One, Science Outreach Initiative Questions for Scientists, July 2017
3. Amol Dighe
Science Corner. Interview, All India Radio, Oct 2017

Eknath Ghate
Talked about Mathematics and Music, on Unwind – Celebrating 70 years of India’s Independence, All India Radio, 6 - 7 pm, August 21, 2017

Shannon Olsson
Shoot for Science with National Geographic, Exhibiting Scientist, 2017

Chandra, Poonam
1. Swedish Science Radio, 21 December 2017
2. Swedish Science Radio, 22 December 2017

S. S. Prabhu
All India Radio, FM107.1 program on Science popularization (in Marathi), November 2016

A. Sule
1. Darwin and Evolution (Interview), IBN Lokmat, January 2018
2. Darwin and Evolution (Interview), NDTV, January 2018

Varadharajan Sundaramurthy
Together with theatre personalities from UK, schools were visited in Bangalore to spread awareness about AMR and encouraged children to evolve a skit based on their understanding of AMR. This was later played in the Jagrithi Theater in Bangalore.

Mukund Thattai
BBC World Service Radio, to speak about the theme of evolution in school curricula, March 2018
Obituaries

M.S. Multani
Full Professor (F), Solid State Physics
Joined TIFR on 01.02.1971

Yash Pal
Full Professor, CRL (Ooty)
Joined TIFR on 01.05.1950

K. P. Parab
Assistant Vigilance Officer, Security
(23.09.1968–02.11.2017)
Joined TIFR on 08.08.1988

Saumyajit Saha
Research Scholar, DBS
(07.07.1992–27.01.2018)
Joined TIFR on 05.03.2013

Avanish Shrivastava
Research Scholar, DBS
Joined TIFR on 30.07.2014

R. R. Simha
Full Professor, Mathematics
Joined TIFR on 25.07.1959
Launch of Vigyan Pratibha Project at HBCSE, Mumbai by Dr. Sekhar Basu (Secretary, DAE) on 31 July 2017

Vigyan Pratibha Students Workshop

Vigyan Pratibha Teachers Workshop

Vigyan Pratibha Outdoor Activities with Students

The cover graphic has been created by Christopher Evans and Karan Jani at the Center for Relativistic Astrophysics, Georgia Institute of Technology, and is reproduced with their kind permission.
Cosmic firework from colliding neutron stars, observed in gravitational and electromagnetic waves during August 2017.