Summary of work from Fundamental Interactions Laboratory, Gravitation Group, TIFR (2005-2008):

The thrust area for research in the group is the study of fundamental interactions employing low energy tools, with emphasis on gravity and quantum electrodynamical forces. The experimental tools are high sensitivity torsion balances, laser cooled atoms and Bose-Einstein Condensates (BEC). The developments related to laser cooling has also led to some studies on atom-light interactions and atomic physics aspects of BECs. Our major results during the past three years are a) measurement of the quantum van der Waals (C_3) coefficient by a novel method of measuring the reflection of ultra-cold atoms of Rubidium from magnetic thin film surfaces (2005), b) measurement of phase transition and relaxation properties of thin film magnetic materials of interest in condensed matter physics using atom reflection from magnetic thin films as the tool, c) the production of a Bose-Einstein condensate in an optical dipole trap backed by one of the fastest loading cold atomic beam source (2006-07), d) and production of BEC is a one-dimensional optical lattice with the largest ever number density and single site occupation, and the study of mean field controlled expansion dynamics at high density (2008).

The BEC in TIFR lab is the first and at present the only one in India. It is also one of the few optical trap BECs (spinor condensates produced through all optical route, without magnetic traps) around the world. Recently we have also produced and studied a 'Raman MOT' (magneto-optical trap), in which the cooling and repumping beams are in a Raman configuration. At present we are building an ultra-cold atom experiment with facility for magneto-optical trapping, atomic fountain, steep trap for single atoms studies, high density magnetic and optical traps for the production and study of BEC and degenerate fermions. Various isotopes of Rubidium and Potassium can be trapped and cooled.

Building and operating Torsion balances to study extremely weak forces have been our strength for over two decades, and we have designed and built a planar torsion balance for studying the Casimir force and its finite temperature corrections, based on my original proposal in 1995. We had the first ever detection of finite temperature effects, albeit low statistical accuracy, in 2004. New experiment to study gravity with a differential torsion balance is initiated. Also, we have a new proposal for testing higher dimensional theories that predict modifications to standard gravity.

There are two areas of foundational aspects under theoretical study, with significant results. One is the aspect of quantum correlations and we established the tight link between classical conservations laws and quantum correlations. We have proved that local hidden variable theories do not respect fundamental conservation laws even at the ensemble average level. There is a definite long term program for the reformulation of quantum theory incorporating correctly the role of quantum phase. The stand taken, with good logical evidence, is that Einstein locality is valid in quantum phenomena.

Another major activity is the study of dynamics and relativity with the realization that all of physics has to be understood and described in the 'once-given' universe with all its matter content and is gravity present during every experimental test. This Cosmic Relativity re-establishes the absolute frame and absolute time in physics and its predictions of anisotropy of time dilations of transported clocks and also the non-invariance of the speed of light relative to inertially moving observers have been verified now by analysis and experiments in our laboratory. Contentious as may be, these are verifiable results from careful precision experiments, and further discussions and debates on these important issues are expected.

Publications with titles indicating the specific results (2005-2008): (Major results are highlighted in the margin

1. *A simple and inexpensive electronic wavelength-meter using a dual-output photodiode,* Sanjukta Roy, Saptarishi Chaudhuri and C. S. Unnikrishnan, American Journal of Physics **73**, 571-573 (2005).
2. *Conservation laws, Correlations functions and Bell's inequalities,* C. S. Unnikrishnan, Europhysics Letters **69**, 489-495 (2005).
3. *On the gravitational deflection of light and particles,* C. S. Unnikrishnan, Current Science (Indian Acad. Sci.), **88**, 1155-1159 (2005).
4. *The incompatibility between local hidden variable theories and the fundamental conservation laws,* C. S. Unnikrishnan, Pramana – Jl. Phys. **65**, 359 (2005).
5. *On Einstein's resolution of the twin clock paradox,* C. S. Unnikrishnan, Current Science 89, 2009 (2005).
6. *Contemplations on our physical links to the universe,* C. S. Unnikrishnan, LEONARDO (MIT Press) **39**, 71 (2006).
7. *Constraint on the gravity of quantum Fermi pressure: a new test of general relativity,* C. S. Unnikrishnan and G. T. Gillies, Phys. Rev. D 73, 101101 (Rapid Comm.), (2006).
8. *High sensitivity probe absorption technique for time-of-flight measurements on cold atoms,* A. K. Mohapatra and C. S. Unnikrishnan, Pramana – Jl. Phys. **66**, 1027 (2006).
9. *Measurement of the van der Waals force using reflection of cold atoms from magnetic thin film atom mirrors,* A. K. Mohapatra and C. S. Unnikrishnan, Europhys. Lett. 73, 839 (2006).
10. *Realisation of an efficient 2D$^+$MOT source of intense cold Rb atomic beam: Experiments and comparison with simulations,* Saptarishi Chaudhuri, Sanjukta Roy and C. S. Unnikrishnan, Physical Review A **74**, 023406 (2006).
11. *Reflection of cold atoms from magnetic thin films: From atom optics to measurement of short-range forces,* A. K. Mohapatra, S. Chaudhuri, S. Roy and C. S. Unnikrishnan, European Physical Journal D **42**, , 287 (2007).
12. *Celestial Optical Interferometry: A new tool for precision laser ranging,* Unnikrishnan and G. T. Gillies, Int. Jl. Mod. Phys. D**17**, 617-626, (2008).
13. *Studies on Cold Atoms Trapped in a Quasi-Electrostatic Optical Dipole Trap***,** Sanjukta Roy, Saptarishi Chaudhuri and C. S. Unnikrishnan, Journal of Physics: Conference Series **80** (2007) 012043.
14. *Evaporative Cooling of Atoms to Quantum Degeneracy in an Optical Dipole Trap*, Saptarishi Chaudhuri, Sanjukta Roy and C. S. Unnikrishnan, Journal of Physics: Conference Series **80** (2007) 012036.
15. *Gravity of Quantum Fermi Pressure: A New Test of General Relativity* (GRF essay honorable mention 2006), C. S. Unnikrishnan and G. T. Gillies, Int. Jl. Mod. Phys. D**17**, 747-753 (2008).
16. *Proposal for an Experiment to Search for Randall-Sundrum type Corrections to Newton's Law of Gravitation,* M. Azam, M. Sami, C. S. Unnikrishnan and T. Shiromizu, Phys. Rev. D**77**, 101101 (Rapid. Comm), (2008).
17. *Equivalence Principles Exotica,* C. S. Unnikrishnan and G. T. Gillies, to appear in Frontiers of Physics - China (Springer-Verlag), 2008.
18. Sanjukta Roy, Saptarishi Chaudhuri and C. S. Unnikrishnan, submitted to Europhysics Letters (2008).

Proceedings and Books (2007-08)

1) *Bose-Einstein Condensation of Weakly Interacting Atoms in an Optical Dipole Trap,* Sanjukta Roy, Saptarishi Chaudhuri and C. S. Unnikrishnan, in Contemporary Optics and Optoelectronics: Proceedings of XXXIII OSI Symposium on Optics and optoelectronics, p423-426, Tata McGraw-Hill, New Delhi (2007).
2) *New Tests and Clarification on Some Conceptual Issues in the Superposition of Monochromatic Light Fields,* Aditya Gilra, Vandna Gokhroo and C. S. Unnikrishnan, Proc. SPIE conference 'The Nature of Light: What are Photons?' (Ed. C. Roychoudhuri, Al. F. Kracklauer and Katherine Creath), San Diego, v6664, article 66640N (2007).
3) *Light and the Observer: New Experiments and a Critique of Our Common Beliefs About Light,* C. S. Unnikrishnan, Proc. SPIE conference 'The Nature of Light: What are Photons?' (Ed. C. Roychoudhuri, Al. F. Kracklauer and Katherine Creath), San Diego, v6664, invited article 66640R (2007).
4) *The Effect of Cosmic Gravity on Clocks Moving Through the Universe,* C. S. Unnikrishnan, in the Proceedings (CD distribution) of the first ESA Colloquium on Scientific and Fundamental Aspects of the Galileo Program, Toulouse, (2007)
5) *New Measurements of the One-Way Speed of Light and its Relation to Clock Comparison Experiments,* C. S. Unnikrishnan, to appear in the Proceedings of the 11th Marcel Grossmann meeting, Berlin, 2006 (2008).
6) *The Equivalence Principle and its Tests in the Context of Gravity, Quantum Mechanics And Cosmology,* C. S. Unnikrishnan, to appear in the Proceedings of the 11th Marcel Grossmann meeting, Berlin, 2006 (2008).
7) *Measurement of the Casimir force above 5 microns and the detection of finite temperature effect,* G. Rajalakshmi, D. Suresh, R. Cowsik and C. S. Unnikrishnan, To appear in the Proceedings of the 11th Marcel Grossmann meeting, Berlin, 2006 (2008).
8) *Physics in the Once Given Universe: New Perspectives on Dynamics, Relativity, Quantum Spectra and The Spin-Statistics Connection,* C. S. Unnikrishnan, to appear in the volume of papers related to the International Conference on Progress in Theoretical Physics, Indian Statistical Institute, Kolkata (2008, World Scientific).
9) *Search for Modified Gravity and Short-Range Forces,* to appear in the Proceedings of the Workshop on Warped Extra Dimensions, Indian Institute of Technology, Kharagpur, 2008.
10) *Bose-Einstein Condensation in a Quasi-Electrostatic Trap,* Saptarishi Chaudhuri, KIRAN, (Special Issue on Best Theses and Posters at National Laser Symposium - 2007), Newsletter of Indian Laser Association, Vol. 19, No.1, April 2008.