

SHRAVAN M. HANASOGE

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RESEARCH INTERESTS Turbulent Convection and Dynamo Action, Machine Learning, Numerical Methods,
Optimal Control and Inverse Problems, Helio- and Asteroseismology, Terrestrial and
Exploration Seismology

EDUCATION Stanford University, CA, USA

Ph.D., Mechanical Engineering *Jan 2004 - Aug 2007*

- Dissertation: Theoretical Studies of Wave Propagation in the Sun
- Advisors: Prof. Parviz Moin, Prof. Philip Scherrer, Dr. Thomas Duvall
- Areas of Study: Numerical Methods and Solar Seismology

M.S., Mechanical Engineering *Sep 2002 - Dec 2003*

Indian Institute of Technology Madras, Chennai, India

B.Tech., Aerospace Engineering *Jul 1998 - May 2002*

ACADEMIC EXPERIENCE Tata Institute of Fundamental Research, Mumbai, India
Department of Astronomy & Astrophysics

Associate Professor *Jan 2018 - present*

Reader *Nov 2013 - Dec 2017*

Princeton University, Princeton Center for Theoretical Science, NJ, USA

Associate Fellow *Sep 2009 - Sep 2011*

Princeton University, Department of Geosciences, NJ, USA
Max Planck Institute for Solar System Research, Göttingen, Germany

Associate Research Scholar *Oct 2008 - Nov 2013*

Stanford University, W. W. Hansen Experimental Physics Laboratory, CA, USA

Postdoctoral Scholar *Oct 2007 - Sep 2008*

Graduate Research Assistant *Jan 2004 - Aug 2007*

Stanford University, Department of Mechanical Engineering, CA, USA

Teaching Assistant *Sep 2002 - Dec 2003*

- Linear Algebra, Solutions of Differential Equations, Numerical Methods for Differential Equations, and Introduction to Engineering Mathematics

EXTERNAL
APPOINTMENTS

- Stanford University, Department of Physics, California, USA
Visiting Scholar *June 2018 - August 2018*
- International Centre for Theoretical Science, Bangalore, India
Joint Faculty Member *March 2014 - present*
- New York University Abu Dhabi, UAE
Research Associate Professor *April 2015 - present*
Co-Principal Investigator, Center for Space Science *April 2015 - present*
- ETH, Department of Earth Sciences, Zürich, Switzerland
Visiting Professor *May 2016 - July 2016*
- New York University, Courant Institute of Mathematical Sciences, NY, USA
Visiting Academic *Sep 2010 - Sep 2013*
- Monash University, Centre for Astrophysics, Melbourne, Australia
Visiting Academic *May 2008 - Aug 2008*

TEACHING AND
SUPERVISION

- Supervising three PhD students at TIFR, Jishnu Bhattacharya (graduation expected 2018), Dattaraj Dhuri (2019), and Krishnendu Mandal (2019)
- Taught graduate-level Fluid Mechanics I, 2014 (a new course at TIFR)
- Taught graduate-level Mathematical Methods I, 2015 and 2016 (a standard course)

SERVICE

- Reviewer for articles from ApJ, ApJL, Astronomy & Astrophysics, Solar Physics, Geophysics Journal International
- External and panel reviewer of NASA heliophysics proposals
- Created SPARC (2008) - publicly available, validated software that can be used to simulate wave propagation in stratified magnetic media (in active use by several groups)
- Organized an international conference on Solar and Stellar Physics (“Advances in Seismology”) at TIFR in December 2015
- Organized an Indo-German Winter School on Solar and Stellar Physics at TIFR in November 2014
- Organized a helio- and terrestrial seismology workshop in March 2010 and March 2011 at the Princeton Center for Theoretical Science

COMPUTING

- Acquired and maintaining SEISMO: a 648-cluster Intel Ivy Bridge cluster (2015 - present)
Parallel computing performed on *Columbia*, *Schirra* (NASA Ames), *Teragrid*

AWARDS AND GRANTS Cray’s APJ Abdul Kalam High Performance Computing award 2017
Early Career Award (from the Department of Science and Technology, India) 2015
Max-Planck Partner Group 2015
Ramanujan Fellowship (Department of Science and Technology, India) 2014
Raised \$600,000 for the period 2011-2014, NASA Heliophysics division (proposal: ‘*Iterative inversions of sunspot and supergranular subsurface structure*’)

INDUSTRIAL COLLABORATION Shell Technology Centre, Bangalore, India: Applying Renormalization Group theory to generate coarse-scale models of porosity (2014 – 2018)
Development of seismic imaging methods to study the Earth’s sub-surface (2017 – 2019)

PRESS Nature Physics News & Views
Proceedings of the National Academy of Sciences
Max-Planck Institute press release
NYU press release
American Physical Society
Princeton University press release
MIT Technology Review (physics arXiv blog)
New Scientist
Astronomy Now
Futurity (NYU press release)
MSNBC
Huffington Post
Times of India
Der Tagesspiegel

CONFERENCES SCORE meeting on convection in the Sun, Heidelberg (2017)
iBUKS conference on Waves in the Sun, Leuven (2016)
Division Meeting, International Astronomical Union, Honolulu (2015)
Solar Dynamo Frontiers, Boulder (2015)
American Geophysical Union, San Francisco (2014)
Dynamics of the Solar Atmosphere, Pune (2014)
HELAS, Göttingen (2014)
Astronomical Society of India, Mohali (2014)
Asian-Pacific Solar Physics Meeting, Hangzhou (2013)
SDO7, Maryland (2013)
Eclipse on the Coral Sea, Cairns (2012)
ISSI Helioseismology meeting, Bern (2012)
QUEST Seismology Meeting, Iceland (2011)
Waves, Pau (2009)
Evershed meeting, Bangalore (2008)
HELAS, Freiburg (2008)
SOHO/GONG (2006, 2008)

UNIVERSITY TALKS IUCAA Colloquium (2017)
Cambridge University, Department of Earth Sciences (2017)
Center for Space Science at New York University Abu Dhabi (2016)
Cambridge University, Department of Earth Sciences (2014)
TIFR Mumbai, TIFR Hyderabad (2014)
Monash University Public Lecture (2013)
Monash University Astrophysics and Applied Mathematics Colloquia (2013)
University of Tokyo (2013)
Lamont-Doherty Earth Observatory, Columbia University (2013)

Department of Astronomy, University of Rochester (2012)
High Altitude Observatory Colloquium (2007, 2012)
Institute of Geophysics, Paris (2012)
Caltech Seismological Laboratory (2011)
Sommerfeld Theory Colloquium, Ludwig Maximilian University (2011)
MIT Applied Mathematics (2011)
Harvard CFA (2008, 2011)
Center for Atmospheric Sciences, Courant Institute, NYU (2011)
Center for Cosmology and Particle Physics, NYU (2010)
Magneto-Fluid dynamics seminar, Courant Institute, NYU (2010)
Institute of Geophysics, ETH, Zürich (2010, 2011, 2012, 2013, 2016)
Rice University (2 seminars, 2010)
Department of Geophysics, Yale University (2010)
Max-Planck-Institut for Solar System Research (2009)
Indian Institute of Astrophysics (2008)

PATENT

Shravan Hanasoge, Tarje Nissen-Meyer (Oxford University) & Johan Robertsson (ETH, Zürich) 2014, *Wave Propagation and Imaging Method*. Patent: WO2014117284 A2

Peer reviewed publications (2006 - present)

- BOOK 57. [Imaging Convection and Magnetism in the Sun](#)
[Hanasoge, S. M.](#), 2015, Springer Applied Mathematical Briefs series
- BOOK CHAPTERS 56. [Solar Dynamics, Rotation, Convection and Overshoot](#)
[Hanasoge, S. M.](#), [Miesch M. S.](#), [Roth, M.](#), [Schou, J.](#), [Schüssler, M.](#), & [Thompson, M. J.](#) 2015
Space Science Reviews, 24H; [arXiv e-print 1503.08539](#)
55. [Interpreting Cross Correlations in Seismology](#)
[Hanasoge, S. M.](#) 2015
'Extra-terrestrial Seismology', ed. Vincent Tong, Cambridge University Press
- INVITED REVIEWS 54. [Seismic Sounding of Convection in the Sun](#)
[Hanasoge, S. M.](#), [Gizon, L.](#) & [Sreenivasan, K. R.](#) 2016
Annual Review of Fluid Mechanics , 48, 191; [arXiv e-print 1503.07961](#)
53. [The Quest To Understand Supergranulation and Large-Scale Convection in the Sun](#)
[Hanasoge, S. M.](#) & [Sreenivasan, K. R.](#) 2014
Solar Physics, 289, 3403; [arXiv e-print 1401.0110](#)
- TERRESTRIAL SEISMOLOGY/
EXOPLANETS 52. [Discrete Wave Equation Upscaling](#)
[Fichtner, A.](#) & [Hanasoge, S. M.](#) 2017
Geophysics Journal International, Express Letters, 209, 353
51. [Measurements and kernels for source-structure inversions in noise tomography](#)
[Hanasoge, S. M.](#) 2014
Geophysical Journal International, 196, 971; [arXiv e-print 1310.0857](#)
50. [Interpreting Cross Correlations of One-bit Filtered Seismic Noise](#)
[Hanasoge, S. M.](#) & [Branicki, M.](#) 2013
Geophysical Journal International, 195, 1811; [arXiv e-print 1308.3646](#)
49. [Seismic Constraints on Rotation of Solar-like Star and Mass of Exoplanet](#)
[Gizon, L.](#) et al., [Hanasoge, S. M.](#), & [Sreenivasan, K. R.](#) 2013
Proceedings of the National Academy of Sciences, 110, 33; [arXiv e-print 1308.4352](#)
48. [Detectable Seismic Consequences of the Interaction of a Primordial Black Hole with Earth](#)
[Luo, Y.](#), [Hanasoge, S. M.](#), [Tromp, J.](#), & [Pretorius, F.](#) 2012
Astrophysical Journal, 751, 16; [arXiv e-print 1203.3806](#)
47. [The Influence of Noise Sources on Cross Correlation Amplitudes](#)
[Hanasoge, S. M.](#) 2012
Geophysical Journal International, 192, 295; [arXiv e-print 1210.2313](#)
46. [Noise Cross-Correlation Sensitivity Kernels](#)
[Tromp, J.](#), [Luo, Y.](#), [Hanasoge, S. M.](#), & [Peter, D.](#) 2010

NUMERICAL
METHODS

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

Dhuri, D. Hanasoge, S. M., Perlekar, P., & Robertsson, J. O. A. 2017
Physical Review E, 95, 4, 043306; arXiv e-print 1704.03172

44. Lattice-Boltzmann Formulation for Electromagnetic Wave Propagation

Hanasoge, S. M., Succi, S., & Orszag, S. A. 2011
Europhysics Letters, 96, 14002; arXiv e-print 1108.2651

43. An absorbing boundary formulation for the stratified, linearized ideal MHD equations based on an unsplit, convolutional perfectly matched layer

Hanasoge, S. M., Komatitsch, D., & Gizon, L. 2010
Astronomy and Astrophysics, 522, 87; arXiv e-print 1003.0725

INTERDISCIPLINARY 42. Asteroseismic inference of solar-like latitudinal differential rotation in an ensemble of stars

Benomar, O. et al. 2017, *Science*, in review

41. Fast Automated Detection of Oscillation Power in Stellar Spectra using Machine Learning

Nath, R., Benomar, O., Hanasoge, S. M. et al. 2017
Monthly Notices of the Royal Astronomical Society, in review

40. Renormalization Group theory outperforms other approaches in statistical comparison between upscaling techniques for porous media

Shravan Hanasoge, Umang Agarwal, Kunj Tandon, & J. M. A. Vianney Koelman 2017
Physical Review E, 96, 033313 ; arXiv e-print 1709.04768

39. Asteroseismic determination of fundamental parameters of Sun-like stars using multilayered neural networks

Verma, K., Hanasoge, S. M., Bhattacharya, J., Antia, H. M., & Krishnamurthi, G. 2016
Monthly Notices of Royal Astronomical Society 461, 4206; arXiv e-print 1602.00902

38. Spatio-Spectral Concentration of Convolutions

Hanasoge, S. M. 2016
Journal of Computational Physics, 313, 674; arXiv e-print 1603.02101

37. Anomalously Weak Solar Convection

Hanasoge, S. M., Duvall, T. L., Jr., & Sreenivasan, K. R. 2012
Proceedings of the National Academy of Sciences, 109, 30; arXiv e-print 1206.3173

36. Transient Solar Oscillations Driven by Primordial Black Holes

Kesden, M. & Hanasoge, S. M. 2011
Physical Review Letters, 107, 1101; arXiv e-print 1106.0011

35. Smoldering Combustion of ‘Incense’ Sticks - Experiments and Modeling

Mukunda, H. S., Basani, J., Shravan, H. M., & Binoy Philip, 2007
Combustion Science and Technology, 179, 1113

34. Measurement process and inversions using helioseismic normal-mode coupling
Hanasoge, S. M. 2018
Astrophysical Journal, in review
33. Iterative inversion of synthetic travel times successful at recovering sub-surface profiles of supergranules
Bhattacharya, J., Hanasoge, S. M., Birch, A. C. & Gizon, L. 2017
Astronomy & Astrophysics, 607, 129; [arXiv e-print 1708.03464](#)
32. Seismic sensitivity of Normal-mode Coupling to Lorentz stresses in the Sun
Hanasoge, S. M. 2017
Monthly Notices of the Royal Astronomical Society, 470, 2780, [arXiv e-print 1705.09431](#)
31. Finite-frequency sensitivity kernels in spherical geometry for time-distance helioseismology
Mandal, K., Bhattacharya, J., Halder, S. & Hanasoge, S. M. 2017
Astrophysics Journal, 842, 89, [arXiv e-print 1705.04020](#)
30. Sensitivity of Helioseismic Measurements of Normal-mode Coupling to Flows and Sound-speed Perturbations
Hanasoge, S. M., Woordard, M. F., Antia, H. M., Gizon, L. & Sreenivasan, K. R. 2017
Monthly Notices of the Royal Astronomical Society, 470, 1404, [arXiv e-print 1705.08204](#)
29. Strategies in the Seismic Inference of Supergranular Flows in the Sun
Bhattacharya, J. & Hanasoge, S. M. 2016
Astrophysical Journal 826, 105; [arXiv e-print 1605.09315](#)
28. Simulating Acoustic Waves in Spotted Stars
Papini, E., Birch, A. C., Gizon, L. & Hanasoge, S. M. 2015
Astronomy & Astrophysics, 577, 145; [arXiv e-print 1503.06032](#)
27. Frequency Shifts of Resonant Modes of the Sun due to Near-Surface Convective Scattering
Bhattacharya, J., Hanasoge, S. M., & Antia, H. M. 2015
Astrophysical Journal, 806, 246; [arXiv e-print 1505.04048](#)
26. Full Waveform Inversion of Solar Interior Flows
Hanasoge, S. M. 2014
Astrophysical Journal, 797, 23; [arXiv e-print 1410.1981](#)
25. Additional Evidence Supporting a Model of Shallow, High-Speed Supergranulation
Duvall, T. L., Jr., Hanasoge, S. M. & Chakraborty, S. 2014
Solar Physics, 289, 3421; [arXiv e-print 1404.2533](#)
24. Full Waveform Inversion for Time-Distance Helioseismology
Hanasoge, S. M. & Tromp, J. 2014
Astrophysical Journal, 784, 69; [arXiv e-print 1401.7603](#)
23. Propagation of seismic waves through a spatio-temporally fluctuating medium: Homogenization
Hanasoge, S. M., Gizon, L., & Bal, G. 2013
Astrophysical Journal, 773, 101; [arXiv e-print 1306.620](#)

22. Testing Helioseismic-Holography Inversions for Supergranular Flows Using Synthetic Data
Dombroski, D., Birch, A. C., Braun, D. C., & Hanasoge, S. M. 2013
Solar Physics, 282, 361; [arXiv e-print 1211.6886](#)
21. Seismic Probes of Solar Interior Magnetic Structure
Hanasoge, S. M., Birch, A. C., Gizon, L., & Tromp, J. 2012
Physical Review Letters, 109, 10, 1101; [arXiv e-print 1207.4352](#)
20. Subsurface Supergranular Vertical Flows as Measured Using Large Distance Separations in Time-Distance Helioseismology
Duvall, T. L., Jr. & Hanasoge, S. M. 2012
Solar Physics, 287, 71; [arXiv e-print 1207.6075](#)
19. Multichannel Three-Dimensional SOLA Inversion for Local Helioseismology
Jackiewicz, J., Birch, A. C., Gizon, L., [Hanasoge, S. M.](#), Ruffio, J.-B., & Svanda, M. 2012
Solar Physics, 276, 19; [arXiv e-print 1109.2712](#)
18. The Adjoint Method Applied to Time-Distance Helioseismology
Hanasoge, S. M., Birch, A. C., Gizon, L., Tromp, J. 2011
Astrophysical Journal, 738, 100; [arXiv e-print 1105.4263](#)
17. Validated helioseismic inversions for 3-D vector flows
Svanda, M., Gizon, L., [Hanasoge, S. M.](#), & Ustyugov, S. D. 2011
Astronomy & Astrophysics, 530, 148; [arXiv e-print 1104.4083](#)
16. Modeling the Sub-surface Structure of Sunspots
H. Moradi, C. Baldner, R. Bogart, D. Braun, R. Cameron, T. Duvall, L. Gizon, D. Haber, S. Hanasoge, J. Jackiewicz, E. Khomenko, R. Komm, P. Rajaguru, M. Rempel, M. Roth, R. Schlichenmaier, H. Schunker, H. Spruit, K. Strassmeier, M. Thompson, S. Zharkov
Solar Physics 267, 1; [arXiv e-print 0912.4982](#)
15. Seismic Constraints on Interior Solar Convection
Hanasoge, S. M., Duvall, T. L., Jr., & DeRosa, M. L. 2009
Astrophysical Journal Letters, 712L, 98; [arXiv e-print 1001.4508](#)
14. A Wave Scattering Theory of Solar Seismic Power Halos
Hanasoge, S. M. 2009
Astronomy and Astrophysics, 503, 595; [arXiv e-print 0906.4671](#)
13. Sub-wavelength Resolution Imaging of the Solar Deep Interior
Hanasoge, S. M. & Duvall, T. L., Jr., 2009
Astrophysical Journal, 693, 1678; [arXiv e-print 0812.0119](#)
12. Surface-Focused Seismic Holography of Sunspots: II. Expectations from Numerical Simulations Using Sound-Speed Perturbations
Birch, A. C., Braun, D. C., [Hanasoge, S. M.](#), & Cameron, R., 2009
Solar Physics, 254, 17
11. Numerical Models of Travel-time Inhomogeneities in Sunspots
Moradi, H., [Hanasoge, S. M.](#), & Cally, P. S., 2009
Astrophysical Journal Letters, 690, 72; [arXiv e-print 0808.3628](#)

10. Multiple Scattering of Waves by a Pair of Gravitationally Stratified Flux Tubes
 Hanasoge, S. M. & Cally, P. S., 2009
Astrophysical Journal, 697, 651; arXiv e-print 0812.1284

9. Impact of Locally Suppressed Wave Sources on Helioseismic Traveltimes
 Hanasoge, S. M., Couvidat, S., Rajaguru, S. P., & Birch, A. C. 2008
Monthly Notices of the Royal Astronomical Society, 391, 1931; arXiv e-print 0707.1369

8. Global Effects of Local Sound-Speed Perturbations in the Sun: A Theoretical Study
 Hanasoge, S. M. & Larson, T. P. 2008
Solar Physics, 251, 91; arXiv e-print 0711.1877

7. Helioseismology of Sunspots: a Case Study of NOAA Region 9787
 Gizon, L., Schunker, H., Baldner, C. S., Basu, S., Birch, A. C., Bogart, R. S., Braun, D. C., Cameron, R., Duvall, T. L., Jr., Hanasoge, S. M., Jackiewicz, J., Roth, M., Stahn, T., Thompson, M. J., & Zharkov, S., 2008
Space Science Reviews, 144, 249

6. f-mode Interactions with Thin Flux Tubes: The Scattering Matrix
 Hanasoge, S. M., Birch, A. C., Bogdan, T. J., & Gizon, L., 2008
Astrophysical Journal 680, 774; arXiv e-print 0711.2076

5. Seismic Halos around Active Regions: A Magnetohydrodynamic Theory
 Hanasoge, S. M., 2008
Astrophysical Journal 680, 1457; arXiv e-print 0712.3578

4. Validation of Helioseismology through Forward Modeling: Realization Noise Subtraction and Kernels
 Hanasoge, S. M., Duvall, T. L., Jr., & Couvidat, S., 2007
Astrophysical Journal 664, 1234

3. The Solar Acoustic Simulator: Applications and Results
 Hanasoge, S. M. & Duvall, T. L., Jr., 2007
Astronomical Notes 328, 319

2. Computational Acoustics in Spherical Geometry: Steps toward Validating Helioseismology
 Hanasoge, S. M. et al., 2006
Astrophysical Journal 648, 1268

1. Scattering of Acoustic Waves by a Magnetic Cylinder: Accuracy of the Born Approximation
 Gizon, L., Hanasoge, S. M., & Birch, A. C., 2006
Astrophysical Journal 643, 549; arXiv e-print 0803.3839