Maarten Valentijn de Hoop
Curriculum Vitae

Personal data

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Education

1979 – 1984	Enrolled as a student in the Department of Physics, Utrecht University, the Netherlands
1981	B.Sc.-Degree in physics with mathematics and astronomy (cum laude), Utrecht University
1984	M.Sc.-Degree in theoretical physics (cum laude), Utrecht University
1992	Ph.D.-Degree in technical sciences (cum laude), Delft University of Technology, the Netherlands

Professional career

2015 – present	Simons Chair in Computational and Applied Mathematics and Earth Science, Rice University, Houston TX, USA
2007 – present	Visiting professor at the Graduate University of Chinese Academy of Sciences, Beijing, China
2001 – present	Part-time visiting professor and visiting associate professor at the Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA, USA
2005 – 2015	Professor at the Department of Mathematics and at the Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette IN, USA
2003 – 2005	Professor at the Center for Wave Phenomena, the Department of Mathematical and Computer Sciences, Colorado School of Mines, Golden CO, USA
1997 – 2003	Associate professor at the Center for Wave Phenomena, the Department of Mathematical and Computer Sciences, Colorado School of Mines, Golden CO, USA

1995 – 1997	Research assistant professor and visiting professor at the Center for Wave Phenomena, the Department of Mathematical and Computer Sciences, Colorado School of Mines, Golden CO, USA
1992 – 1995	Senior research scientist and programme leader at Schlumberger Cambridge Research, Cambridge, England
1985 – 1992	Research geophysicist at Koninklijke/Shell Exploratie en Produktie Laboratorium, Rijswijk, the Netherlands

Other positions

2010 – 2018	Scientific adviser, Corporate Science and Technology, Total American Services, Inc.
2010 – 2011	DARPA, Transparent Earth Initiative
2004 – 2005	Consultant, Corporate Science and Technology, Total American Services, Inc.

Awards and honors

- Recipient of the 1996 J. Clarence Karcher Award, Society of Exploration Geophysicists;
- Recipient of an unrestricted grant from the 1998–1999 DuPont Educational Aid Program;
- Recipient of the award for young scientists, International Society for Analysis, its Applications and Computation, 2001.

Memberships in professional societies

- SIAM (Society for Industrial and Applied Mathematics);
- AMS (American Mathematical Society);
- IOP (Institute of Physics) Fellow (since 2001);
- AGU (American Geophysical Union);

Main professional experience

scattering, imaging and inverse problems, deep learning
theoretical and computational seismology, geodesy, magnetohydrodynamics

- multi-dimensional imaging, inverse scattering and tomography;

- nonlinear inverse boundary value problems: direct and iterative reconstruction; geometric inverse problems; inverse spectral problems; inverse problems with nonlinear wave interaction; coupled physics and hybrid inverse problems;

- deep learning and inverse problems, data-driven discovery;

- development of multiscale methods and nonlinear theories of generalized functions applied to scattering and inverse scattering in media of low regularity, and in highly discontinuous and random media;

- large-scale computational modeling of acoustic, elastic and electromagnetic wave phenomena in complex media, earthquakes, normal modes and fast iterative methods for nonlinear inverse problems; development of approaches based on techniques from microlocal analysis and computational harmonic analysis, structured matrix based methods, and massively parallel algorithms.

Extramural activities

- 11/1994, 3/1995 – visiting scientist at the Institute for Mathematics and its Applications (Minneapolis MN; host: Professor G. Papanicolaou); in-depth course presentation on Seismic Applications of Pseudodifferential Operators;

- 7/29 - 8/10/1996 – Euler International Mathematical Institute (St. Petersburg, Russia; host: Professor M. Belishev); presentations on Microlocally Nonlinear Inversion;

- 10/30 - 11/ 2/1996 – workshop on New Methods in Analysis, Science University of Tokyo (Mito, Japan; host: Professor G. Nakamura); overview presentations on One-way Wave and Asymptotic Ray Methods and their Application to Geophysical Inverse Problems;

- 6/29 - 6/30/1998 – Tongji University (Shanghai, China; host: Professor Zaitian Ma); 7/ 6 - 7/ 7/1998 – Jianghan Petroleum University (Jingzhou, China; host: Professor Haimin Guo); short course presentations on Generalized Screen Methods and Asymptotic Inversion;

- 8/ 3 - 8/21/1998 – Mathematical Geophysics Summer School, Stanford University (CA); in-depth course presentation on the Application of Fourier-Integral and Pseudo-Differential Operators and Differential Geometry to Problems associated with Migration and Inversion of Seismic Data;

- 10/ 1 - 12/ 7/2001 – semester on Inverse Problems, Mathematical Sciences Research Institute, Berkeley (CA); general member;

- 1/ 6 - 1/18/2003 – On Partial Differential Equations, Inverse Problems and Non-Linear Analysis, Pan-American Advanced Studies Institute (Santiago, Chile); minicourse on Microlocal Analysis of Seismic Inverse Scattering;

- 11/ 9 - 11/21/2003 – Institute for Pure and Applied Mathematics, University of California, Los Angeles (CA); core participant Inverse Problems: Computational Methods and Emerging Applications;

- 12/ 1 - 12/31/2003 – Institut für Technische Mathematik, Geometrie und Bauinformatik, University of Innsbruck (Innsbruck, Austria); guest professor;

- 5/ 1 - 5/10/2005 – Erwin Schrödinger International Institute for Mathematical Physics (Vienna, Austria); research scientist and participant Modern Methods of Time-Frequency Analysis;

- 11/28 - 12/21/2011 – Isaac Newton Institute for Mathematical Sciences (Cambridge, England); visiting fellow, Inverse Problems;

- 6/ 1 - 6/30/2015 – Institut Henri Poincaré (Paris, France); CNRS visiting professor, Program on Inverse Problems;

- 9/17 - 9/21/2018 – Institut für Angewandte und Numerische Mathematik, Karlsruhe Institute of Technology, Research University in the Helmholtz Association (Karlsruhe, Germany); short course in the Summer School on Full Waveform Inversion – Mathematics and Geophysics;

- 9/ 1 - 9/30/2019, 11/ 3 - 11/27/2019 – semester on Microlocal Analysis, Mathematical Sciences Research Institute, Berkeley (CA); research professor;

- 7/ 5 - 7/13/2007, 6/26 - 7/ 3/2008, 7/ 5 - 7/16/2010, 7/ 4 - 7/14/2011, 6/26 - 7/ 6/2012, 7/ 4 - 7/12/2013, 7/ 7 - 7/11/2014, 7/ 6 - 7/14/2015, 7/ 4 - 7/12/2016, 7/ 1 - 7/ 7/2017, 6/25 - 6/29/2018, 6/26 - 7/ 3/2019 – College of Earth Science, (Graduate) University of Chinese Academy of Sciences (Beijing, China); course on Methods of Imaging Earth's Interior.

Courses taught

- calculus (with Mathematica recitation), differential equations, linear algebra, real analysis, advanced engineering mathematics, numerical analysis, and partial differential equations for the undergraduate curriculum; independent study on continuum mechanics for the undergraduate curriculum;

- advanced real analysis (from H.L. Royden, Real Analysis, Prentice Hall), functional analysis (from J.B. Conway, A Course in Functional Analysis, Springer), and advanced applied mathematics (from J.P. Keener, Principles of Applied Mathematics, Addison-Wesley); independent studies on microlocal analysis and symplectic geometry (from L. Hörmander, The Analysis of Linear Partial Differential Operators, Vols. 1 and 3, Springer), and on the theory of distributions (from L. Schwartz, Mathematics for Physical Sciences, Hermann) for the graduate curriculum;

- special topics: applied microlocal analysis (from own lecture notes), and inverse problems (from own lecture notes) for the graduate curriculum;

- mathematical theory of seismology for the graduate curriculum (in the Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA; from own lecture notes).

Student supervision

- former M.Sc. students at Delft University of Technology

  - H.C. Serafini; thesis: 'Splitting of acoustic waves in fluid media in the third-order Thiele approximation' (Department of Applied Mathematics and Informatics, 1991);
  - J.P.L. Mourik; thesis: 'Fast computation of synthetic seismograms in a piecewise continuously layered fluid' (Department of Electrical Engineering, 1992);

- former Ph.D. student at Delft University of Technology

  - M.J.N. van Stralen; thesis: 'Directional decomposition of electromagnetic and acoustic wave fields' (Department of Electrical Engineering, 1994-1997);

- former Ph.D. students at the Center for Wave Phenomena, Colorado School of Mines

  - S. Brandsberg-Dahl; thesis: 'Imaging-inversion and migration velocity analysis in the scattering-angle/azimuth domain' (Department of Geophysics, 1998-2001);
  - J.H.L. Le Rousseau; thesis: 'Microlocal analysis of wave-equation imaging and generalized-screen propagators' (Department of Geophysics, 1998-2001);
  - A.E. Malcolm; thesis: 'Data continuation for data regularization and internal multiples' (Department of Geophysics, 2000-2005);

  former Ph.D. co-advisee at the Center for Wave Phenomena, Colorado School of Mines

  - H. Douma; thesis: 'A hybrid formulation of map migration and wave-equation-based migration using curvelets' (Department of Geophysics, 2001-2006);

- former Ph.D. students at the Geo-Mathematical Imaging Group, Purdue University

  - V. Brytik; thesis: 'Mode decoupling of the elastic wave equation, 'reverse-time migration', and sensitivity analysis of wave-equation tomography using wave packets' (Department of Mathematics, 2005-2010);
  - S. Wang; thesis: '3D modeling of time-harmonic seismic waves via a massively parallel structured multifrontal solver and applications' (Department of Earth and Atmospheric Sciences, 2007-2012);
  - L. Qiu; thesis: 'An inverse boundary value problem for the Helmholtz equation: Conditional stability and convergence of multi-level, multi-frequency iterative methods for nonlinear reconstruction of the wavespeed' (Department of Mathematics, 2008-2013);

- P. Kepley; thesis: 'Inverse boundary value problem for the wave equation: Reconstruction using boundary control and redatuming' (Department of Mathematics, 2012-2018);

• former Ph.D. students at the Geo-Mathematical Imaging Group, Rice University

- R. Ye; thesis: 'Discontinuous Galerkin method with a modified penalty flux for the modeling of acousto-elastic waves, coupled to rupture dynamics, in a self-gravitating earth' (Department of Earth, Environmental and Planetary Sciences, 2011-2018);

- J. Zhai; thesis: 'Analysis of inverse boundary value problems for elastic waves' (Department of Computational and Applied Mathematics, 2013-2018);

- X. Liu; thesis: 'Structured matrix algorithms for solving the Helmholtz equation' (Department of Computational and Applied Mathematics, 2013-2019);

- J. Shi; thesis: 'Normal modes, surface-wave and time-harmonic body-wave computational modeling and inverse modeling on unstructured, deformable tetrahedral meshes' (Department of Earth, Environmental and Planetary Sciences, 2012-2019);

• current Ph.D. students at the Geo-Mathematical Imaging Group, Rice University

- H. Jasperson; project: 'Clustering of precursory signals, forecasting with machine learning, learning fault dynamics';

- J. Lara Benitez; project: 'Design of neural operators, deep learning and (inverse) boundary value problems for the waves';

- N. Erfanian; project: 'Simplicial neural networks, fracture networks and topological data analysis, forecasting';

• former M.Sc. student at the Geo-Mathematical Imaging Group, Rice University

- J. Ye; thesis: 'Revisiting the computation of normal modes in SNREI models of planets' (Applied Physics, 2015-2017);

• former Ph.D. co-advisees

- S.-K. Foss; thesis: 'Depth consistent PP and PS angle tomography' (Department of Mathematics, Faculty of Information Technology, Mathematics and Electrical Engineering, Norwegian University of Science and Technology, Trondheim, Norway, 2001-2004);

- P. Wang; thesis: 'Imaging structure at and near the core mantle boundary using a generalized Radon transform' (Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA, 2001-2007);

- – Q. Cao; thesis: 'Seismic imaging of the mantle transition zone' (Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA, 2006-2011);

- – X. Shang; thesis: 'Inverse scattering: Theory and application to the imaging of Earth's seismic discontinuities' (Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA, 2007-2013);

- – M. Berra; thesis: 'Frame based Gaussian beams for evolution equations' (Dipartimento di Matematica "Giuseppe Peano", University of Torino, Italy, 2013-2015);

- – H. Matchette-Downes; thesis: 'Some studies on the computation and interpretation of seismic interface waves and modes in Earth's mantle' (Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge MA, 2015-2021);

- supervision of eleven visiting graduate students, M. Gustafsson (Department of Applied Electronics, Lund University, Lund, Sweden; 1998), B.L.G. Jonsson (Division of Electromagnetic Theory, Department of Signal, Sensors and Systems, Royal Institute of Technology, Stockholm, Sweden; 1999), C.C. Stolk (Mathematics Department, Utrecht University, Utrecht, the Netherlands; 2000), A.A. Duchkov (Institute of Geophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russia; Summer 2004); T. Wiik (Department of Petroleum Engineering and Applied Geophysics, Norwegian University of Science and Technology, Trondheim, Norway; Spring 2010); S. Park (Department of Energy Resources Engineering, Seoul National University, Korea; Spring 2011); W. Shi (Department of Mathematics, Nanjing University, China; 2012-2013); P. Zhang (Tsinghua University, Beijing, China; 2013-2014); H. Quiceno (Mathematical Sciences Department, Universidad EAFIT, Medellin, Colombia; Spring 2017); A. Molina-Aguilera (Instituto Andaluz de Geofisica and Departamento de Fisica Teorica y del Cosmos, Facultad de Ciencias, Universidad de Granada, Spain; Fall 2017); K. Shukla (Boone Pickens School of Geology, Oklahoma State University; 2018).

Post-doctoral advisees

- - A.A. Duchkov (2005-2009);
- - M. Carlsson (2008-2011);
- - H. Wendt (2008-2011);
- - S.F. Holman (2010-2013);
- - Z. Guo (2011-2013);
- - H. Pham (2012-2013);
- - J. Tittelfitz (2013-2015);
- - J. Chen (2013-2015);
- - P. Caday (2015-2018);

- V. Katsnelson (2015-2018);
- C. Wong (2016-2019);
- T. Saksala (2017-2020);
- Y. Assylbekov (2019-2021);
- M.A. Puthawala (2019-2022);
- L. Baldassari (2021-2023).

Departmental committees and service at the Colorado School of Mines

- co-leader of the Center for Wave Phenomena, Colorado School of Mines; the Center for Wave Phenomena is an interdisciplinary graduate research program between the Department of Mathematical and Computer Sciences and the Department of Geophysics (1995-2005);
- member of the tenure and promotion committee (2003-2005);
- member of the Graduate Advisory Committee in the Department of Mathematical and Computer Sciences (1999-2003);
- member of the Charles Henry Green Chair Search Committee in the Department of Geophysics (2003-2004);
- member of the Research Council (2001-2004).

Departmental committees and service at Purdue University

- founder and director of the Geo-Mathematical Imaging Group (2007-2015);
- director of the Center for Computational and Applied Mathematics (2005-2011);
- member of primary committee in the Department of Mathematics (2005-2015);
- member of personnel committee in the Department of Mathematics (2005-2010, 2011-2012, 2014-2015);
- member of promotions subcommittee in the Department of Mathematics (2007-2008, 2009-2010, 2012-2013);
- member of Department of Mathematics Head Search Advisory Committee (2006-2007);
- member of Alumni and Corporate Relations Committee in the Department of Earth and Atmospheric Sciences (2005-2012);
- member of Search Committee in geodynamics and active tectonics in the Department of Earth and Atmospheric Sciences (2006-2007);
- member of the Computing Research Institute Steering Committee (2005-2009);
- member of the Cyber Center Director Search Committee (2005-2006);
- member of the Computing Research Institute Director Search Committee (2006-2007);
- member of the College of Science Strategic Relations Search Committee (2008-2009);
- member of the College of Science International Committee (2012-2013).

Departmental committees and service at Rice University

- director of the Geo-Mathematical Imaging Group (2015-present);
- chair of the Undergraduate Committee in the Department of Computational and Applied Mathematics (2017-2019);
- member of the Graduate Committee in the Department of Computational and Applied Mathematics (2015-2017);
- member of the Search Committee for the Department Chair in Computational and Applied Mathematics (2017-2018);
- member of the Operations Committeee of the Energy and Environment Initiative (2016-present)
- member of the Graduate Council (2016-2018);
- member of the School of Engineering Strategic Planning Committee (2017-2018).

National and international professional activities and service

- member of editorial boards: Wave Motion (2000 - 2008), Journal of Applied Geophysics (2001 - 2006), Journal of Pseudodifferential Operators and Applications (2010 - present), Inverse Problems (2000 - 2003, 2017 - 2021; executive editorial board: 2021 - present), Journal of Inverse and Ill-Posed Problems (2018 - present), Inverse Problems and Imaging (2020 - present), International Journal on Geomathematics (2019 - present);

- member of international advisory panel: Inverse Problems (1/1/2004 - 12/31/2007);

- guest editor: Special Issue on Inverse Problems of IMACS Mathematics and Computers in Simulation (Vol.50 (5-6) 1999), Special Issue of Wave Motion honoring A.T. de Hoop's 75th birthday (Vol.41 (3) 2004);

- panel member: NSF (Directorate for Mathematical and Physical Sciences);

- member of the Research Committee of the Society of Exploration Geophysicists;

- district representative (district 4) of the Society of Exploration Geophysicists (2007-2010);

- member at large of the Committee on Science Policy of the American Mathematical Society (2010-2013);

- member of the scientific committee of the Geomathematics Programme at PIMS (Pacific Institute for the Mathematical Sciences; 2008-present);

- member of the scientific advisory board of the DK+ "Computational Interdisciplinary Modelling", University of Innsbruck, Innsbruck, Austria (2011-2013);

- member of the external review committee of the Department of Mathematics and Statistics, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia (2009);

- member of the steering committee for College of Petroleum Engineering and Geosciences (CPG) Global Partnership, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia (2018-present);

- Ph.D. examination: Massachusetts Institute of Technology (Department of Earth, Atmospheric and Planetary Sciences and Department of Mathematics), Utrecht University (Utrecht, the Netherlands, Mathematics Department), Université Paris 7 (Institut de Physique du Globe de Paris, Département de Sismologie), Université de Pau et des Pays de l'Adour (Pau, France, Mathématiques Appliquées); Lund Institute of Technology, Lund University (Lund, Sweden, Centre for Mathematical Sciences); University of Twente (Enschede, the Netherlands, Department of Applied Mathematics); Université Paris-Est-Créteil Val-de-Marne (Crétreil, France, Department of Mathematics); Universidad EAFIT (Medellin, Colombia, Mathematical Sciences Department); Université Grenoble Alpes (Grenoble, France, Laboratoire Jean Kuntzmann).

- **organizer of conferences, workshops and special programs**:

  - member program committee Mathematical Methods in Geophysical Imaging III, SPIE - International Symposium on Optical Science, Engineering and Instrumentation (San Diego CA, July 1995);

  - member technical program committee 69th Annual Meeting of the Society of Exploration Geophysicists (Houston TX, October 1999);

  - co-organizer Society of Exploration Geophysicists Summer Research Workshop on Synergies in Geophysical, Medical and Space Imaging (Newport Beach CA, July 2001);

  - member scientific committee IPAM (Institute for Pure and Applied Mathematics) / SIAM/EMS conference on Applied Inverse Problems: Theoretical and Computational Aspects (UCLA Lake Arrowhead Conference Center, May 2003);

  - member organizing committee PIMS (Pacific Institute for the Mathematical Sciences) Geophysical Inversion Workshop (Calgary, Canada, July 2003);

  - member international program committee International Conference on Inverse Problems: Modeling and Simulation (Fethiye, Turkey, June 2004);

  - member scientific committee Waves 2005 (Brown University RI, June 2005);

  - co-organizer Workshop on Subsalt Imaging Problems (Colorado School of Mines CO, July 2005);

  - co-organizer Workshop on Microlocal Analysis and Harmonic Analysis in Inverse Problems (C.I.R.M., Marseille, France, March 2007);

- member steering committee Applied Inverse Problems (Vancouver, Canada, June 2007);

- program leader (chair) of program on Random Media (2007-08) at the Statistical and Applied Mathematical Sciences Institute (Research Triangle Park, NC);

- member organizing committee SIAM Conference on Imaging Science (San Diego CA, July 2008);

- member scientific committee (IMA PI conference on) Dynamical Systems in Physiological Modeling (Purdue University, West Lafayette IN, October 2008);

- member scientific committee International Conference on Generalized Functions (Vienna, Austria, August-September 2009);

- co-organizer program on Inverse Problems and Applications (Mathematical Sciences Research Institute, Berkeley CA, Fall 2010);

- member organizing committee International Symposium on Geophysical Imaging with Localized Waves (Sanya, Hainan, China, July 2011);

- member organizing committee SIAM Conference on Imaging Science (Philadelphia PA, May 2012);

- member organizing committee scientific program on Inverse Problems and Applications (Institut Mittag-Leffler, Stockholm, Sweden, Spring 2013);

- member scientific committee Applied Inverse Problems (Helsinki, Finland, May 2015);

- organizer MATH + X Symposium on Seismology and Inverse Problems (Houston TX, January 2017);

- co-organizer workshop on Recent Advances in Seismic Modeling and Inversion: From Analysis to Applications (Institute for Computational and Experimental Research in Mathematics, Providence RI, November 2017);

- organizer MATH + X Symposium on Data Science and Inverse Problems in Geophysics (Houston TX, January 2018);

- co-organizer mini-workshop on Deep Learning and Inverse Problems (Mathematische Forschungsinstitut Oberwolfach, Germany, March 2018);

- co-organizer DOE workshop on Information is in the Noise: Signatures of Evolving Fracture Systems (Gaithersburg MD, March 2018);

- co-organizer NIPS workshop on Machine Learning for Geophysical and Geochemical Signals (Montréal, Canada, December 2018);

- organizer MATH + X Symposium on Inverse Problems and Deep Learning in Space Exploration (Houston TX, January 2019);

- co-organizer 2nd Annual Machine Learning in Solid Earth Geoscience (Santa Fe NM, March 2019);

– co-organizer 4th Workshop on Inverse Problems, Imaging and PDEs (Jockey Club Institute for Advanced Study, HKUST, Hong Kong, May 2019);

– organizer MATH + X Symposium on Inverse Problems and Deep Learning, Mitigating Natural Hazards (Las Catalinas, Costa Rica, January 2020);

– organizer MATH + X Symposium on Matter under Extreme Conditions in Solar System Giant Planets and Exoplanets, Inverse Problems and Deep Learning (Las Catalinas, Costa Rica, July 2022).

Theses

M.Sc.-thesis 'Geometrical construction of general instanton and BPS-monopole solutions' on the application of differential geometry and topology to construct particular excitations in gauge theories. (Thesis advisers: Professor Dr. G. 't Hooft and Professor Dr. F.A. Bais.)

Ph.D.-thesis 'Directional decomposition of transient acoustic wave fields' on a generalization of the Bremmer coupling series to multi-dimensionally varying media using the calculus of pseudo-differential operators, and its application in inverse scattering. (Thesis advisers: Professor Dr. Ir. A.T. de Hoop and Professor Dr. Ir. P.M. van den Berg, thesis co-adviser: Professor Dr. Ir. J.T. Fokkema.)

Publications

- **Chapters in books**

  1. 'The geometry of elastic waves propagating in an anisotropic elastic medium', in *Springer Lecture Notes in Physics 424*, 1993, pp.131-166, with D.-J. Smit.

  2. 'Wavefield reciprocity and local optimization in remote sensing', *Proceedings* of the symposium on *Wavefields and reciprocity*, Delft University Press, Delft, 1996, pp.49-64.

  3. 'Microlocal analysis of seismic inverse scattering', in *Inside Out, Inverse Problems and Applications*, Mathematical Sciences Research Institute Publications, edited by G. Uhlmann, Cambridge University Press, Cambridge, 2003, pp.219-296.

  4. 'Geophysical modelling with Colombeau functions: Microlocal properties and Zygmund regularity', in *Nonlinear Algebraic Analysis and Applications*, Cambridge Scientific Publishers, Cambridge, 2004, pp.99-110, with G. Hörmann.

  5. 'Elastic-wave inverse scattering based on reverse time migration with active and passive source reflection data', in *Inside Out II, Inverse Problems and Applications*, Mathematical Sciences Research Institute Publications, edited by G. Uhlmann, Cambridge University Press, Cambridge, 2013, pp.411-453, with V. Brytik and R.D. van der Hilst.

- **International (refereed) journals**

1991

1. 'Wave propagation with tunneling in a highly discontinuous layered medium', *Wave Motion 13* (1991) 307-327, with R. Burridge and H.-W. Chang.

2. 'The pseudo-primary field due to a point-source in a finely layered medium', *Geoph. J. Int. 104* (1991) 489-506, with H.-W. Chang and R. Burridge.

1992

3. 'Scalar space-time waves in their spectral-domain first- and second-order Thiele approximations', *Wave Motion 15* (1992) 229-265, with A.T. de Hoop.

1993

4. 'Interface reflections of spherical acoustic waves in the first- and second-order rational parabolic approximations and their artifacts', *J. Acoust. Soc. Am. 93* (1993) 22-35, with A.T. de Hoop.

5. 'Waves in stratified viscoelastic media with microstructure', *J. Acoust. Soc. Am. 94* (1993) 2884-2894, with R. Burridge, K. Hsu, L. Le and A. Norris.

1994

6. 'Elastic wave up/down decomposition in inhomogeneous and anisotropic media: an operator approach and its approximations', *Wave Motion 20* (1994) 57-82, with A.T. de Hoop.

1995

7. 'The geometry of the hyperbolic system for an anisotropic perfectly elastic medium', *Comm. Math. Phys. 167* (1995) 255-300, with D.-J. Smit.

1996

8. 'Beyond effective medium theory: pulse stabilization for multimode wave propagation in high-contrast layered media', *SIAM J. Appl. Math. 56* (1996) 256-276, with P. Lewicki and R. Burridge.

9. 'Acoustic, elastodynamic and electromagnetic wavefield computation – a structured approach based on reciprocity', *Proceedings* of the symposium on *Large-scale structures in acoustics and electromagnetics* (Commission on Physical Sciences, Mathematics, and Applications), National Academic Press, Washington D.C., 1996, pp.72-88, with A.T. de Hoop.

10. 'Quasi Monte-Carlo integration over $S^2 \times S^2$ for migration $\times$ inversion', *Inverse Problems 12* (1996) 219-239, with C. Spencer.

11. 'Generalization of the Bremmer coupling series', *J. Math. Phys. 37* (1996) 3246-3282.

12. 'An invariant imbedding analysis of general wave scattering problems', *J. Math. Phys. 37* (1996) 3854-3881, with A.J. Haines.

1997

13. 'Generalized Radon transform inversions for reflectivity in anisotropic elastic media', *Inverse Problems 13* (1997) 669-690, with N. Bleistein.

14. 'Design of sparse matrix representations for the propagator used in the BPM and the directional wave field decomposition', *Optical and Quantum Electronics 29* (1997) 179-197, with M.J.N. van Stralen and H. Blok.

1998

15. 'Generalized Bremmer series with rational approximation for the scattering of waves in inhomogeneous media', *J. Acoust. Soc. Am. 104* (1998) 1943-1963, with M.J.N. van Stralen and H. Blok.

16. 'Multiparameter inversion in anisotropic elastic media', *Geoph. J. Int. 134* (1998) 757-777, with R. Burridge, D. Miller and C. Spencer.

1999

17. 'The resolving power of seismic amplitude data: An anisotropic inversion/migration approach', *Geophysics 64* (1999) 852-873, with C. Spencer and R. Burridge.

2000

18. 'Generalization of the phase-screen approximation for the scattering of acoustic waves', *Wave Motion 31* (2000) 43-70, with J.H. Le Rousseau and R.-S. Wu.

19. 'Some remarks on nonlinear AVA inversion in anisotropic media', *Geophysics 65* (2000) 158-166, with F.A. Neves.

20. 'Approximate dispersion relations for qP-qSV waves in transversely isotropic media', *Geophysics 65* (2000) 919-933, with M. Schoenberg.

21. 'Wavefield reciprocity and optimization in remote sensing', *Proc. R. Soc. Lond. A (Mathematical, Physical and Engineering Sciences) 456* (2000) 641-682, with A.T. de Hoop.

22. 'Maslov asymptotic extension of generalized Radon transform inversion in anisotropic elastic media: A least-squares approach', *Inverse Problems 16* (2000) 519-562, with S. Brandsberg-Dahl.

23. 'Exact constructions of square-root Helmholtz operator symbols: The focusing quadratic profile', *J. Math. Phys. 41* (2000) 4881-4938, with L. Fishman and M.J.N. van Stralen.

24. 'Uniform asymptotic expansion of the generalized Bremmer series', *SIAM J. Appl. Math. 60* (2000) 1302-1329, with A.K. Gautesen.

2001

25. 'Modeling and imaging with the scalar generalized-screen algorithms in isotropic media', *Geophysics 66* (2001) 1551-1568, with J.H. Le Rousseau.

26. 'Scalar generalized-screen algorithms in transversely isotropic media with a vertical symmetry axis', *Geophysics 66* (2001) 1538-1550, with J.H. Le Rousseau.

27. 'Wave field decomposition in anisotropic fluids: A spectral theory approach', *Acta Appl. Math. 67* (2001) 117-171, with B.L.G. Jonsson.

28. 'Microlocal analysis and global solutions of some hyperbolic equations with discontinuous coefficients', *Acta Appl. Math. 67* (2001) 173-224, with G. Hörmann.

2002

29. 'Microlocal analysis of seismic inverse scattering in anisotropic, elastic media', *Comm. Pure Appl. Math. 55* (2002) 261-301, with C.C. Stolk.

30. 'Challenges of complex media', *The Leading Edge 21* (2002) 587-592, with S. Levin.

31. 'Seismic wavefield 'continuation' in the single scattering approximation: A framework for Dip and Azimuth Moveout', *Can. Appl. Math. Q. 10* (2002) 199-238, with A.E. Malcolm and J.H. Le Rousseau.

32. 'Detection of wave front set perturbations via correlation: Foundation for wave-equation tomography', *Appl. Anal. 81* (2002) 1443-1465, with G. Hörmann.

2003

33. 'Focusing in dip and AVA compensation on scattering-angle/azimuth common image gathers', *Geophysics 68* (2003) 232-254, with S. Brandsberg-Dahl and B. Ursin[1].

34. 'Symplectic structure of wave-equation imaging: A path-integral approach based on the double-square-root equation', *Geoph. J. Int. 153* (2003) 52-74, with J.H. Le Rousseau and B. Biondi.

35. 'Generalized-screen approximation and algorithm for the scattering of elastic waves', *Q. J. Mech. Appl. Math. 56* (2003) 1-33, with J.H. Le Rousseau.

36. 'Uniform asymptotic expansion of the square-root Helmholtz operator and the one-way wave propagator', *SIAM J. Appl. Math. 63* (2003) 777-800, with A.K. Gautesen.

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165. 'Semiclassical inverse spectral problem for seismic surface waves in isotropic media I: Love waves', *Inverse Problems 36* (2020) 075015, doi:10.1088/1361-6420/ab8446, with A. Iantchenko, R.D. van der Hilst and J. Zhai.

166. 'Semiclassical inverse spectral problem for seismic surface waves in isotropic media II: Rayleigh waves', *Inverse Problems 36* (2020) 075016, doi:10.1088/1361-6420/ab8447, with A. Iantchenko, R.D. van der Hilst and J. Zhai.

167. 'Full reciprocity-gap waveform inversion, enabling sparse-source acquisition', *Geophysics 85(6)* (2020) R461-R476, doi:10.1190/geo2019-0527.1, with F. Faucher, G. Alessandrini, H. Barucq, R. Gaburro and E. Sincich.

168. 'Clustering earthquake signals and background noises in continuous seismic data with unsupervised deep learning', *Nature Comm. 11* (2020) 3972, doi:10.1038/s41467-020-17841-x, with L. Seydoux, R. Balestriero, P. Poli, M. Campillo and R. Baraniuk.

169. 'Learning the geometry of wave-based imaging', *Advances in Neural Information Processing Systems 33* (2020) 8318-8329, oral, with K. Kothari and I. Dokmanić.

2021

170. 'Reciprocity-gap misfit functional for Distributed Acoustic Sensing, combining data from passive and active sources' *Geophysics 86(2)* (2021) R211-R220, doi:10.1190/geo2020-0305.1, with F. Faucher and O. Scherzer.

171. 'Recovery of discontinuous Lamé parameters from exterior Cauchy data', *Comm. Partial Differential Equations 46* (2021) 680-715, with P. Caday, V. Katsnelson and G. Uhlmann.

172. 'Planetary normal mode computation: Parallel algorithms, performance, and reproducibility, *IEEE Trans. on Parallel and Distributed Systems 11* (2021) 2609-2622, with J. Shi, R. Li, Y. Xi and Y. Saad.

173. 'Holmgren-John unique continuation theorem for viscoelastic systems', in *Time-dependent Problems in Imaging and Parameter Identification*, edited by B. Kaltenbacher, T. Schuster and A. Wald, Springer Nature Switzerland AG, 2021, pp.287-302, with C.-L. Lin and G. Nakamura.

174. 'Fault detection in an anisotropic elastic medium', *Rendiconti di Matematica e delle sue Applicazioni 42* (2021) 183-195, with A. Aspri, E. Beretta and A. Mazzucato.

175. 'Generic uniqueness and stability for the mixed ray transform in three-dimensional compact simple Riemannian manifolds', *Trans. AMS 374* (2021) 6085-6144, with T. Saksala, G. Uhlmann and J. Zhai.

176. 'Higher-order Hamilton-Jacobi perturbation theory for anisotropic heterogeneous media: Transformation between Cartesian and ray-centred coordinates', *Geophys. J. Int. 226* (2021) 893-927, with E. Iversen, B. Ursin, T. Saksala and J. Ilmavirta.

177. 'Higher-order Hamilton-Jacobi perturbation theory for anisotropic heterogeneous media: Dynamic ray tracing in ray-centred coordinates', *Geophys. J. Int. 226* (2021) 1262-1307, with E. Iversen, B. Ursin, T. Saksala and J. Ilmavirta.

178. 'TRUMPETS: Injective flows for inference and inverse problems', *Uncertainty in Artificial Intelligence '21* (2021) 1269-1278, with K. Kothari, A.E. Khorashadizadeh and I. Dokmanić.

179. 'Determination of a compact Finsler manifold from its boundary distance map and an inverse problem in elasticity', *Communications in Analysis and Geometry* (2021) in print, with J. Ilmavirta, M. Lassas and T. Saksala.

180. 'A high order discontinuous Galerkin method with penalty fluxes for the symmetric form of the anisotropic viscoelastic wave equation', *Computers and Mathematics with Applications 99* (2021) 113-132, with K. Shukla and J. Chan.

181. 'Anatomy of streaming Mars SEIS and pressure data from unsupervised learning', *Bulletin of the Seismological Society of America 111 (6)* (2021) 2964-2981, with S. Barkaoui, P. Lognonné, T. Kawamura, E. Stutzmann, L. Seydoux, R. Balestriero, J.-R. Scholz, G. Sainton, M. Plasman, S. Ceylan, J. Clinton, A. Spiga, R. Widmer-Schnidrig, F. Civilini and W.B. Banerdt.

182. 'A foliated and reversible Finsler manifold is determined by its broken scattering relation', *Pure and Applied Analysis 3-4* (2021) 789-811, with J. Ilmavirta, M. Lassas and T. Saksala.

183. 'Attention network forecasts time-to-failure in laboratory shear experiments', *J. Geophys. Res.: Sold Earth 126* (2021) e2021JB022195, with H. Jasperson, C. Bolton, P. Johnson, R. Guyer and C. Marone.

184. 'Spectral rigidity for spherically symmetric manifolds with boundary', *J. Math. Pures Appl.* (2021) in print, with J. Ilmavirta and V. Katsnelson.

185. 'Globally injective ReLU networks', *J. Mach. Learn. Res.* (2021) in print, with M. Puthawala, K. Kothari and I. Dokmanić.

186. 'Recurrent scattering network detects metastable behavior in polyphonic seismo-volcanic signals for volcano eruption forecasting', *IEEE Trans. Geosc. and Remote Sensing* (2021) doi:10.1109/TGRS.2021.3134198, with A. Bueno, R. Balestriero, S. De Angelis, C. Benítez, L. Zuccarello, R. Baraniuk, J.M. Ibáñez.

187. 'Deep learning architectures for nonlinear operator functions and nonlinear inverse problems', *Mathematical Statistics and Learning* (2021) in print, with M. Lassas and C.A. Wong.

188. 'Interconnected hierarchical structures for fast direct elliptic solution', *J. Sci. Comput.* (2021) in print, with X. Liu, J. Xia and X. Ou.

2022

189. 'A multi-scale Gaussian beam parametrix for the wave equation: The Dirichlet problem', *J. Diff. Eqs. 309* (2022) 949-993, with M. Berra and J.L. Romero.

190. 'Inverse problem for the Rayleigh system with spectral data', *J. Math. Phys.* (2022) in print, with A. Iantchenko.

- **Preprints**

1. 'Non-perturbative approach to computing seismic normal modes in rotating planets' (2019) with J. Shi, R. Li, Y. Xi and Y. Saad.

2. 'Mixed Rayleigh-Stoneley modes: A new probe for Earth's core-mantle boundary' (2020) with H. Matchette-Downes, J. Shi, J. Ye, J. Han and R.D. van der Hilst.

3. 'Reconstruction along a geodesic from sphere data in Finsler geometry and anisotropic elasticity' (2021) with J. Ilmavirta and M. Lassas.

4. 'Stable reconstruction of simple Riemannian manifolds from unknown interior sources' (2021) with J. Ilmavirta, M. Lassas and T. Saksala.

5. 'Recovery of wave speeds and density of mass across a heterogeneous smooth interface from acoustic and elastic wave reflection operators' (2021) with S. Bhattacharyya, V. Katsnelson and G. Uhlmann.

6. 'System of radiative transfer equations for coupled surface and body waves' (2021) with J. Garnier and K. Sølna.

7. 'Convergence rates for learning linear operators from noisy data' (2021) with N.B. Kovachki, N.H. Nelson and A.M. Stuart.

8. 'Universal joint approximation of manifolds and densities by simple injective flows' (2021) with M. Puthawala, I. Dokmanić and M. Lassas.

9. 'Local recovery of a piecewise constant anisotropic conductivity in EIT on domains with exposed corners' (2022) with T. Furuya, C.-L. Lin, G. Nakamura and M. Vashisth.

- **Books in preparation**

   1. *Microlocal Analysis of Imaging with Seismic Body Waves*, with S.F. Holman and G. Uhlmann.

   2. *Mathematical Theory of Seismology*, with K. Brazda, P. Caday, S.F. Holman, G. Hörmann, A. Iantchenko, S. Jimbo, G. Nakamura, H. Pham, G. Uhlmann and J. Zhai.
      - 'On the system of elastic-gravitational equations describing the oscillations of the earth' (2015) with S.F. Holman and H. Pham.
      - 'Variational formulation of Earth's elasto-gravitational deformations under low regularity conditions' (2016) with K. Brazda and G. Hörmann.
      - 'Semi-classical analysis of elastic surface waves' (2017) with A. Iantchenko, G. Nakamura and J. Zhai.

Patents

1. 'Method of processing seismic data' (Generalized Radon Transforms) *UK patent 2322 704* (granted 2nd September 1998) and *US patent 5852588* (issued 22nd December 1998), with R. Burridge and C. Spencer.

Invited talks at conferences

1. 'Imaging-inversion in complex geology', *China Complex Geology Exploration Techniques Conference (Lanzhou, China)* 1999;

2. 'Microlocal analysis of electromagnetic (micro)wave imaging and inversion', *2001 URSI International Symposium on Electromagnetic Theory (Victoria, Canada)*, 2001;

3. 'Microlocal analysis and seismic inverse scattering in anisotropic elastic media', *Workshop on Inverse Problems and Imaging (Pacific Institute for the Mathematical Sciences, University of British Columbia, Vancouver, Canada)*, 2001;

4. 'Microlocal analysis of seismic inversion: Characteristic strips, generalized Radon transform, and differential semblance optimization', *Inverse Problems and Applications (the Mathematical Sciences Research Institute, Berkeley CA)* 2001;

5. 'Seismic inverse scattering in the 'wave-equation' approach', *Inverse Problems and Applications, INdAM Workshop (Cortona, Italy)* 2002;

6. 'Seismic inverse scattering with the double-square-root equation', *Conference of Mathematical Modelling of Wave Phenomena (Växjö, Sweden)* 2002;

7. 'The downward continuation approach to seismic inverse scattering', *Applied Inverse Problems: Theoretical and Computational Aspects (UCLA Lake Arrowhead Conference Center CA)* 2003;

8. 'Aspects of microlocal analysis in global seismology', *Analytic and Geometric Methods in Inverse Problems (Helsinki, Finland)* 2003;

9. 'Aspects of microlocal analysis in global seismology', *Computational Methods for Inverse Problems and Applications (Institute for Pure and Applied Mathematics, University of California, Los Angeles CA)* 2003;

10. 'Advances in seismic transmission and reflection tomography', *Interdisciplinary Inverse Problems: Opening Conference for IPRPI (Rensselaer Polytechnic Institute, Troy NY)* 2004;

11. 'Factorization of seismic inverse scattering operators', *Perspectives in Inverse Problems (Helsinki, Finland)* 2004;

12. 'Imaging of reflection seismic data with curvelets', *Time-Frequency Methods for Pseudodifferential Operators (Erwin Schrödinger International Institute for Mathematical Physics, Vienna, Austria)* 2005;

13. '[The analysis of] Imaging of reflection seismic data with curvelets', *Inverse Problems Reunion Conference I, Institute for Pure and Applied Mathematics (UCLA Lake Arrowhead Conference Center CA)* 2005;

14. 'Inverse scattering, tomography, and interferometry', *IX Workshop on Partial Differential Equations (Instituto Nacional de Matemática Pura e Aplicada, Rio de Janeiro, Brazil)* 2005;

15. 'Analysis of 'wave-equation' imaging of reflection seismic data with curvelets', *Time-Frequency Analysis and Nonstationary Filtering (Banff International Research Station, Banff, Canada)* 2005;

16. 'Earth Science: Geophysics – inverse problems', *NISS/SAMSI Workshop on Collaborations in the Mathematical Geosciences (Research Triangle Park NC)* 2005;

17. 'Analysis of 'wave-equation' imaging of reflection seismic data with curvelets', *Workshop on Imaging from Wave Propagation, Institute for Mathematics and its Applications (Minneapolis MN)* 2005;

18. 'Wave-equation imaging', *Electronic Imaging Science and Technology (San Jose CA)* 2006;

19. 'Multi-scale approach to wave-equation imaging and velocity analysis', *ROSE meeting, Norwegian University of Science and Technology (Trondheim, Norway)* 2006;

20. 'Global seismology, inverse scattering and tomography', *International Symposium on Mechanical Waves in Solids (Hangzhou, China)* 2006;

21. 'Advances in wave equation tomography', *Geophysical Inversion Workshop (Calgary, Canada)* 2006;

22. 'A multi-scale approach to evolution equations with applications in wave-equation imaging and reflection tomography', *Inverse Problems and Applications (Banff International Research Station, Banff, Canada)* 2006;

23. '3-D seismic exploration of the lowermost mantle with inverse scattering and statistical inference', *Earthscope Imaging Science / Computational Infrastructure for Geodynamics Workshop (St. Louis MO)* 2006;

24. 'Wavepackets', *Illinois Applied Harmonic Analysis Seminar (Urbana-Champaign IL)* 2006;

25. 'Inverse scattering of seismic data with the generalized Radon transform – Curvelets, matrix representation, computation', *Symposium on Inverse Problems Honoring Alberto Calderón (Instituto Nacional de Matemática Pura e Aplicada, Rio de Janeiro, Brazil)* 2007;

26. 'Dyadic parabolic decomposition, approximation of functions by wave packets, and evolution equations', *International Conference "Trends in Harmonic Analysis" (Strobl, Austria)* 2007;

27. 'Imaging of structure at and near the core-mantle boundary', *Second VLab Workshop (Minneapolis MN)* 2007;

28. 'Analysis of field-field cross correlations in random media and seismic interferometry in SE Tibet', *Program on Random Media Opening Workshop (SAMSI, Research Triangle Park NC)* 2007;

29. 'Multi-scale techniques in imaging and wave-equation tomography', *CIG/SPICE/IRIS Workshop in Computational Seismology (Jackson NH)* 2007;

30. 'Wave-equation reflection tomography', *PIMS-CINVESTAV, "Mathematics of Oil Exploration Workshop" (Monterrey, Mexico)* 2007;

31. 'Sensitivity analysis of wave-equation tomography: A multi-scale approach', *Integral Geometry and Tomography, An international conference dedicated to Jan Boman's 75-th birthday (Stockholm, Sweden)* 2008;

32. 'Seismic imaging with the generalized Radon transform and double beamforming: A curvelet transform perspective', *Second Symposium on Scattering and Spectral Theory (Recife, Brazil)* 2008;

33. 'Inverse scattering of ScS and SKKS waves: Multi-scale imaging of Earth's core-mantle boundary region', *International symposium "From genome to snowball Earth, Metazoan evolution and habitable planets: Multidisciplinary relations" (Tokyo, Japan)* 2008;

34. 'Seismic imaging: A curvelet transform perspective', *"Unifying Framework for Subsurface Sensing and Imaging" workshop hosted by The Bernard M. Gordon Center for Subsurface Sensing and Imaging Systems (Boston MA)* 2008;

35. 'Evidence of small-scale thermal convection near the CMB from joint multi-scale analysis of seismic imaging and finite element modelling', *IASPEI (Cape Town, South Africa)* 2009;

36. 'Wave-ray duality, and a multi-scale approach to wave propagation and imaging', *Waves 2009 (Pau, France)* 2009;

37. 'Seismic imaging, illumination and partial reconstruction: A 'curvelet' transform perspective', *1st PRIMA Congress (Sydney, Australia)* 2009;

38. 'Nonlinear approximation of functions by sums of wave packets and applications', *International Conference on Generalized Functions (Vienna, Austria)* 2009;

39. 'Elastic-wave inverse scattering and seismic receiver functions', *2009 Joint Meeting of the KMS and AMS (Seoul, Korea)* 2009;

40. 'Multi-scale approach to seismic inverse scattering and partial reconstruction via microdiffraction tomography', *WIPA 2010 Inverse Problems and Applications (Valparaíso, Chile)* 2010;

41. 'Wave-equation reflection tomography', *Mathematics and Algorithms in Tomography (Mathematische Forschungsinstitut Oberwolfach, Germany)* 2010;

42. 'Inverse scattering in the reverse-time "migration" approach', *Workshop on Mathematical and Statistical Methods for Imaging (National Institute for Mathematical Sciences, Incheon, Korea)* 2010;

43. 'Construction and properties of solutions of the acoustic and elastic wave equations with co-efficients of limited smoothness: A multi-scale approach, *Asymptotic Properties of Solutions to Hyperbolic Equations (Imperial College, London, England)* 2011;

44. 'Advances in imaging of reflected waves via cross correlations: Controlled noise – random media – ambient noise', *Passive Imaging in Wave Physics: From Seismology to Ultrasound (Institut d'Etudes Scientifiques de Cargèse, Cargèse, Corsica, France)* 2011;

45. 'Construction, computation, and properties of solutions of the acoustic and elastic wave equations with coefficients of limited smoothness using wave packets', *From Abstract to Computational Harmonic Analysis (Strobl, Austria)* 2011;

46. 'Local analysis of the inverse problem associated with the Helmholtz equation – Lipschitz stability and iterative reconstruction', *Inverse Problems in Science and Engineering (Isaac Newton Institute for Mathematical Sciences, Cambridge, England)* 2011;

47. 'Reconstruction of the metric of a Riemannian manifold from local boundary diffraction travel times' *PASI-CIPPDE Inverse Problems and PDE Control (Pan-American Advanced Studies Institute, Santiago, Chile)* 2012;

48. 'Reverse-time-migration based inverse scattering using the dyadic parabolic decomposition of phase space', *Phase Space Methods for Pseudodifferential Operators (Erwin Schrödinger International Institute for Mathematical Physics, Vienna, Austria)* 2012;

49. 'Local analysis of the inverse boundary value problem for the Helmholtz equation and iterative reconstruction', *Computational Inverse Problems (Mathematische Forschungsinstitut Oberwolfach, Germany)* 2012;

50. 'Stability estimates for the inverse boundary value problem for the Helmholtz equation and iterative reconstruction', *UCL Centre for Inverse Problems: Opening Meeting (University College London, England)* 2013;

51. 'Stability estimates for the inverse boundary value problem for the Helmholtz equation and iterative reconstruction', *Full Waveform Inversion: From Near Surface to Deep (Muscat, Oman)* 2013;

52. 'Construction, computation, and properties of solutions of the acoustic and elastic wave equations: A multi-scale approach', *International Workshop on Multiscale Modeling, Simulation and Inversion (KAUST, Saudi Arabia)* 2013;

53. 'Wave packets, analysis of seismic data, and (tomographic) inverse problems', *New Trends in Applied Harmonic Analysis: Sparse Representations, Compressed Sensing and Multifractal*

Analysis (CIMPA, Mar del Plata, Argentina) 2013;

54. 'Recovery of the metric of a Riemannian manifold from local boundary diffraction travel times', *Geometry and Inverse Problems (Banff International Research Station, Banff, Canada)* 2013;

55. 'Local analysis of inverse boundary value problems in seismology and iterative reconstruction', *Modelling, Control and Inverse Problems for the Planet Earth in all Its States (Institut Henri Poincaré, Paris, France)* 2013;

56. 'Inverse problem of electroseismic conversion', *Theoretical and Applied Computational Inverse Problems (Erwin Schrödinger International Institute for Mathematical Physics, Vienna, Austria)* 2014;

57. 'Recovery of the metric of a Riemannian manifold from quasi-microseismicity data', *International Workshop Inverse Problems and Integral Geometry (Immanuel Kant Baltic Federal University, Kalingrad, Russia)* 2014;

58. 'Full waveform inversion: Iterative regularization and convergence', *Lofoten Seminar at Spitsbergen (Longyearbyen, Svalbard)* 2015;

59. 'Construction of high-frequency direct waves generated by interior point sources from the Neumann-to-Dirichlet map', *Passive Imaging and Monitoring in Wave Physics (Institut d'Etudes Scientifiques de Cargèse, Cargèse, Corsica, France)* 2015;

60. 'Seismic applications – Parallel randomized structured direct solvers for multi-frequency full waveform inversion', *Second EAGE Workshop on High Performance Computing for Upstream (Dubai, UAE)* 2015;

61. 'Uniqueness of seismic inverse source problems modelling microseismicity and ruptures', *Workshop on Inverse Problems, Imaging and PDEs (Jockey Club Institute for Advanced Study, HKUST, Hong Kong)* 2015;

62. 'Seismic inverse problems: Iterative reconstruction with bounded frequency boundary data', *Computational Seismology Workshop (Tsinghua Sanya International Mathematics Forum, Sanya, China)* 2016;

63. 'Inverse problems in seismology with a view to the mantle', *Melt in the Mantle (Isaac Newton Institute for Mathematical Sciences, Cambridge, England)* 2016;

64. 'Dirichlet-to-Neumann maps in geophysics and inverse problems', *Dirichlet-to-Neumann Maps: Spectral Theory, Inverse Problems and Applications (Casa Matemática Oaxaca - Banff International Research Station, Oaxaca, Mexico)* 2016;

65. 'Controlling multiple scattering in wavefields without knowing the wavespeed in bounded domains containing conormal singularities', *LIASFMA Workshop on Control and Inverse Problems for Partial Differential Equations (Zhejiang University, Hangzhou, China)* 2016;

66. 'Frame-based multi-scale Gaussian beams, wavefield approximation and boundary value problems', *Sparse Interpolation, Rational Approximation and Exponential Analysis (Casa Matemática Oaxaca - Banff International Research Station, Oaxaca, Mexico)* 2016;

67. 'Scattering control for the wave equation with an unkown wavespeed containing conormal singularities', *Workshop on Inverse Problems, Imaging and PDEs (Jockey Club Institute for Advanced Study, HKUST, Hong Kong)* 2016;

68. 'Scattering control and inverse problem for the wave equation with piecewise smooth wave speeds', *Full Waveform Inversion and Velocity Analysis (Institute for Pure and Applied Mathematics, University of California, Los Angeles CA)* 2017;

69. 'Scattering control and inverse problem for the wave equation with piecewise smooth wave speeds', *Computational Inverse Problems for Partial Differential Equations (Mathematische Forschungsinstitut Oberwolfach, Germany)* 2017;

70. 'Scattering control without knowing the wave speed', *Passive Imaging and Monitoring in Wave Physics: From Seismology to Ultrasound (Institut d'Etudes Scientifiques de Cargèse, Cargèse, Corsica, France)* 2017;

71. 'Frame-based multi-scale Gaussian beams, wavefield approximation and boundary value problems', *Harmonic Analysis, Geometric Measure Theory and Applications (CIMPA, Buenos Aires, Argentina)* 2017;

72. 'Planetary spectral rigidity', *Workshop on Inverse Problems, Imaging and PDEs (Jockey Club Institute for Advanced Study, HKUST, Hong Kong)* 2018;

73. 'Nonlinear responses from the interaction of two progressing waves at an interface', *Inverse Problems in the Alps II (Obergurgl, Austria)* 2018;

74. 'Nonlinear responses from the interaction of two progressing waves at an interface and associated inverse problem', *Inverse Problems Network Meeting 3 (UCL, London, England)* 2018;

75. 'Inverse problem with the boundary distance functions on Finsler manifolds in anisotropic elasticity', *INdAM Workhop on Reconstruction Methods for Inverse Problems (Rome, Italy)* 2018;

76. 'Inverse problems for seismic surface waves – A semiclassical analysis perspective', *Forum on Scientific and Engineering Computing, Institute of Computational Mathematics and Scientific/Engineering Computing, Chinese Academy of Sciences (Beijing, China)* 2018;

77. 'Unique recovery of faults and dislocations from coseismic displacement data', *Workshop on Inverse Problems, PDE and Geometry (Jyväskylä, Finland)* 2018;

78. 'Deep neural-network architectures arising in seismic-inverse problems', *Recent Advances and the Road Ahead, Annual Meeting Society of Exploration Geophysicists (Anaheim, CA)* 2018;

79. 'Generalization and regularization in deep learning for nonlinear inverse problems', *Workshop on Recent Advances in Machine Learning and Computational Methods for Geoscience, Institute for Mathematics and its Applications (Minneapolis MN)* 2018;

80. ' Unsupervised learning for identification of seismic signals', *European Geosciences Union General Assembly (Vienna, Austria)* 2019;

81. ' Recovery of piecewise smooth Lamé parameters for local exterior data', *Probing the Earth and the Universe with Microlocal Analysis (Banff International Research Station, Banff, Canada)* 2019;

82. 'Inverse problems in anisotropic elasticity and seismology', *11th Annual Meeting on Inverse Problems (Lanzhou, China)* 2019;

83. 'Deep learning for identification and classification of seismic signals, of fault dynamics and waves', *Passive Imaging and Monitoring in Wave Physics: From Seismology to Ultrasound (Institut d'Etudes Scientifiques de Cargèse, Cargèse, Corsica, France)* 2019;

84. 'Spectral inverse problems for the earth', *Inverse Days 2019 (Jyväskylä, Finland)* 2019;

85. 'Deep learning in wave-based imaging and inverse problems', *SIAM Conference on Imaging Science (Toronto, Canada)* 2020, virtual;

86. 'Deep learning for seismic signal identification, classification, denoising, forecasting and imaging', *Artificially Intelligent Earth Exploration Workshop: Teaching the Machine How to Characterize the Subsurface (Muscat, Oman)* 2020, virtual;

87. 'Deep learning architectures for nonlinear operator functions and nonlinear inverse problems', *Computational Inverse Problems for Partial Differential Equations (Mathematische Forschungsinstitut Oberwolfach, Germany)* 2020, virtual;

88. 'Globally injective ReLU networks, injective flows and uncertainty quantification', *Deep Learning for Inverse Problems (Mathematische Forschungsinstitut Oberwolfach, Germany)* 2021, virtual;

89. 'Globally injective ReLU networks, injective flows and uncertainty quantification', *The XIII international scientific conference and young scientist school "Theory and Numerics of Inverse and Ill-posed Problems" (Novosibirsk, Akademgorodok, Russia)* 2021, virtual;

90. 'Deep learning and inference for seismic inverse problems', *Intelligent Illumination of the Earth (KAUST, Saudi Arabia)* 2021, virtual.

Invited seminars and colloquia

1. *Wave field decomposition in the direct and inverse acoustic scattering problems*, Center for the Mathematics of Waves, University of Delaware, *Newark DE*, October 1990;

2. *Generalization of the Bremmer coupling series*, Courant Institute, New York University, *New York NY*, November 1992;

3. *A comparison between the even- and odd-order Thiele approximations to the one-way wave operator in the space-time domain*, Institute of Geophysics, University of Texas, *Austin TX*, February 1993;

4. *A comparison between the even- and odd-order Thiele approximations to the one-way wave operator in the space-time domain*, Bullard Laboratories, Department of Earth Sciences, University of Cambridge, *Cambridge*, *England*, May 1993;

5. *Progress in full-wave and asymptotic-ray inversion in anisotropic media*, Institute of Theoretical Geophysics, Departments of Earth Sciences and Applied Mathematics and Theoretical Physics, University of Cambridge, *Cambridge*, *England*, March 1995;

6. *Heterogeneity, anisotropy, and their disguises in seismological multi-parameter inversion*, Institute of Theoretical Geophysics, Departments of Earth Sciences and Applied Mathematics and Theoretical Physics, University of Cambridge, *Cambridge*, *England*, November 1996;

7. *Aspects of multiparameter inversion in anisotropic solid media*, Department of Computational and Applied Mathematics, Rice University, *Houston TX*, October 1996;

8. *Generalized Bremmer series: Convergence, asymptotics, numerical issues*, Department of Electromagnetic Theory, Lund University / Lund Institute of Technology, *Lund*, *Sweden*, August 1997;

9. *Generalized Bremmer series: Convergence, asymptotics, numerical issues*, Department of Electromagnetic Theory, Royal Institute of Technology, *Stockholm*, *Sweden*, August 1997;

10. *Some remarks on nonlinear, multi-azimuth, AVA inversion*, Workshop Sobre Caracterização e Engenharia de Reservatórios, Unicamp, *Campinas SP*, *Brazil*, September 1997;

11. *Generalized Radon Transform inversion and multipathing*, Centre de Recherche en Géophysique, Ecôle des Mines de Paris, *Paris*, *France*, April 1998;

12. *Generalized screens: Theory and algorithms*, Northwest Geology Research Institute, *Lanzhou*, *China*, June 1998;

13. *Maslov asymptotic extension of Generalized Radon Transform inversion in anisotropic elastic media* and *Inversion based on the Generalized Bremmer Series*, Earth Resources Laboratory, Department of Earth, Atmospheric and Planetary Sciences, MIT, *Cambridge MA*, November 1998;

14. *Maslov asymptotic extension of Generalized Radon Transform inversion in anisotropic elastic media: A least-squares approach*, Department of Mechanical and Manufacturing Engineering, University of Calgary, *Calgary*, *Canada*, February 1999;

15. *Maslov asymptotic extension of Generalized Radon Transform inversion in anisotropic media: A least-squares approach*, Mathematics Department, Iowa State University, *Ames IA*, February 1999;

16. *Inversion for singular medium perturbations in the presence of caustics*, Department of Mathematics, Statistics and Computer Science, Växjö University, *Växjö*, *Sweden*, April 1999;

17. *Maslov asymptotic extension of Generalized Radon Transform inversion in anisotropic elastic media*, Department of Petroleum Engineering and Applied Geophysics, Norwegian University of Science and Technology, *Trondheim*, *Norway*, May 1999;

18. *Inversion for singular medium perturbations in the presence of caustics*, Electromagnetics Laboratory, Helsinki University of Technology, *Helsinki*, *Finland*, June 1999;

19. *Inversion for singular medium perturbations in anisotropic elastic media: A Generalized Radon Transform approach*, Department of Mathematics, Gunma University, *Kiryu*, *Japan*, August 1999;

20. *Seismic imaging, inversion and velocity analysis with multi pathing*, Department of Applied Earth Sciences, Delft University of Technology, *Delft*, *the Netherlands*, February 2000;

21. *Recent advances in elastodynamic imaging and inversion, and characterization of heterogeneities*, Department of Earth, Atmospheric and Planetary Sciences, MIT, *Cambridge MA*, May 2000;

22. *Microlocal methods and algorithms for seismic inversion*, Institut für Technische Mathematik, Geometrie und Bauinformatik, University of Innsbruck, *Innsbruck*, *Austria*, June 2000;

23. *Symplectic structure of wave-equation imaging and inversion*, Laboratoire de Mathématiques Appliquées, Université de Pau et des Pays de l'Adour, *Pau*, *France*, February 2001;

24. *Tomography in complex media: An approach based upon microlocalization*, Bullard Laboratories, Department of Earth Sciences, University of Cambridge, *Cambridge*, *England*, May 2001;

25. *Microlocal methods in seismic tomography*, Österreichische Mathematische Gesellschaft and Institut für Technische Mathematik, Geometrie und Bauinformatik, University of Innsbruck, *Innsbruck*, *Austria*, May 2001;

26. *The impact of microlocal analysis on exploration seismology*, Berkeley Seismological Laboratory, Department of Earth and Planetary Science, University of California at Berkeley, *Berkeley CA*, November 2001;

27. *Seismic wavefield continuation in the single scattering approximation*, Serbian Academy of Arts and Sciences (SANU), *Belgrade*, former *Yugoslavia*, March 2002;

28. *Seismic inverse scattering in the wave-equation approach*, Department of Mathematical Sciences, Rensselaer Polytechnique Institute, *Troy NY*, April 2002;

29. *The impact of microlocal analysis on exploration seismology*, Institut de Physique du Globe de Paris, *Paris, France*, May 2002;

30. *Microlocal analysis of artifacts in seismic inverse scattering in the presence of caustics*, Institute of Applied Mathematics, University of British Columbia, *Vancouver, Canada*, November 2002;

31. *Microlocal analysis and computational aspects of the downward continuation approach to seismic imaging, inversion and tomography*, Department of Mathematics and Statistics, Wichita State University, *Wichita, KS*, April 2003;

32. *Feasibility of imaging Earth's lowermost mantle*, Seismological Laboratory, Division of Geological and Planetary Sciences, California Institute of Technology, *Pasadena, CA*, November 2003;

33. *The role of microlocal analysis in seismic inverse scattering*, Applied and Computational Mathematics, Division of Engineering and Applied Science, California Institute of Technology, *Pasadena, CA*, November 2003;

34. *The role of microlocal analysis in seismic inverse scattering*, Department of Applied Mathematics, University of Crete, *Heraklion, Greece*, March 2004;

35. *Introduction to seismic inverse scattering*, Theme Year in Mathematics 2003-2004, Inverse Problems and Related Topics, *Helsinki, Finland*, May 2004;

36. *The impact of microlocal analysis on seismic imaging*, Institute of Geophysics, Russian Academy of Sciences, Siberian Branch, *Novosibirsk, Russia*, July 2004;

37. *Nonlinear aspects of seismic inverse scattering*, Department of Mathematics, Purdue University, *West Lafayette, IN*, November 2004;

38. *Imaging of reflection seismic data with curvelets*, Centre for Mathematical Sciences, Lund Institute of Technology / Lund University, *Lund, Sweden*, May 2005;

39. *Analysis of wave-equation tomography and imaging with curvelets*, Department of Mathematics and Statistics, Wichita State University, *Wichita, KS*, February 2006;

40. *Advances in imaging Earth's interior*, Department of Geophysics, School of Earth and Space Sciences, Peking University, *Beijing, China*, May 2006;

41. *Multi-scale aspects of wave-equation imaging and tomography*, Department of Mathematics, Harbin Institute of Technology, *Harbin, China*, May 2006;

42. *A multi-scale approach to evolution equations with applications in wave-equation imaging and reflection tomography*, Department of Mathematics, University of Washington, *Seattle, WA*, August 2006;

43. *Advances in imaging Earth's interior*, Mathematics in Science and Society, Department of Mathematics, University of Illinois at Urbana-Champaign, *Urbana, IL*, October 2006;

44. *Multi-scale approach to evolution equations with applications in seismic imaging*, Department of Mathematics, Penn State University, *State College, PA*, November 2007;

45. *Inverse scattering and wave-equation tomography with wave packets*, Department of Mathematics, University of Vienna, *Vienna, Austria*, May 2008;

46. *Inverse scattering and wave-equation tomography with wave packets*, Laboratoire d'Analyse et de Mathématiques Appliquées, Paris XII (Creteil), *Paris, France*, May 2008;

47. *Inverse scattering and wave-equation tomography – Imaging Earth's deep interior*, Department of Mathematics, University of Kentucky, *Lexington, KY*, October 2008;

48. *Inverse scattering and wave-equation tomography – Imaging Earth's deep interior*, IAMCS-KAUST Seminar, Texas A & M University, *College Station, TX*, February 2009;

49. *Inverse scattering and wave-equation tomography – Imaging Earth's deep interior*, School of Mathematics, Georgia Institute of Technology, *Atlanta, GA*, March 2010;

50. *Solution constructions, using wave packets, of the wave equation with coefficients of limited smoothness*, Laboratoire Jacques-Louis Lions, Université Pierre et Marie Curie, *Paris, France*, May 2010;

51. *Wave-equation imaging and inverse scattering: Multi-scale techniques and applications to the mantle beneath Hawaii*, Berkeley Seismological Laboratory, Department of Earth and Planetary Science, University of California at Berkeley, *Berkeley, CA*, November 2010;

52. *Construction, computation, and properties of solutions of the acoustic and elastic wave equations with coefficients of limited smoothness*, Institute of Wave and Information, School of Electronic and Information Engineering, Xi'an Jiaotong University, *Xi'an, China*, June 2011;

53. *Seismic imaging and inverse scattering: A curvelet transform perspective*, Department of Mathematics, Chinese University of Hong Kong, *Hong Kong, China*, August 2011;

54. *Elastic-wave inverse scattering with active and passive source reflection data*, Department of Mathematics, University College London, *London, England*, December 2011;

55. *Local analysis of the inverse boundary value problem associated with the Helmholtz equation*, Institute of Computational Mathematics and Operations Research, Department of Mathematical Sciences, Tsinghua University, *Beijing, China*, July 2012;

56. *Local analysis of the inverse boundary value problem for the Helmholtz equation and iterative reconstruction*, Department of Mathematical Sciences, Rensselaer Polytechnic Institute, *Troy, NY*, September 2012;

57. *Revealing Earth's interior: A geo-mathematical perspective*, Bold Aspirations and Visitor Lecture Series, University of Kansas, *Lawrence, KS*, September 2012;

58. *Construction, computation, and properties of solutions of the wave equation with coefficients of limited smooothness*, Dipartimento di Matematica "Guido Castelnuovo", Università di Roma "La Sapienza", *Rome, Italy*, February 2013;

59. *Revealing Earth's interior: From compressive imaging to nonlinear multi-scale iterative reconstruction*, Department of Earth and Space Sciences, UCLA, *Los Angeles, CA*, April 2013;

60. *Stability estimates for the inverse boundary value problem for the Helmholtz equation and iterative reconstruction*, Department of Mathematics, Stanford University, *Stanford, CA*, October 2013;

61. *Spatio-temporal imaging of ruptures and the discrete-time dependent inverse source problem for the wave equation*, Dipartimento di Matematica "Francesco Brioschi", Politecnico di Milano, *Milan, Italy*, June 2014;

62. *Revealing Earth's interior: From compressive imaging to nonlinear multi-scale iterative reconstruction*, Institute of Geology and Geophysics, Chinese Academy of Sciences, *Beijing, China*, July 2014;

63. *Earth as an unstructured mesh: Can we solve the seismic inverse problem?*, Department of Earth and Planetary Sciences, Harvard University, *Cambridge, MA*, October 2014;

64. *The seismic inverse problem: Stability and reconstruction*, Mathematics Program, New York University Abu Dhabi, *Abu Dhabi, UAE*, October 2015;

65. *Seismic inverse problems*, IMPACT Distinguished Lecture, School of Mathematics, Georgia Institute of Technology, *Atlanta, GA*, October 2015;

66. *Uniqueness of seismic inverse source problems modeling microseismicity and ruptures* and *Construction of high-frequency direct waves generated by virtual interior point sources from the Neumann-to-Dirichlet map*, Dipartimento di Matematica e Geoscienze, Sezione di Matematica e Informatica, Universtità degli Studi di Trieste, *Trieste, Italy*, December 2015;

67. *Seismic inverse problems: Revealing Earth's interior*, Lagrange Lecture, Dipartimento di Matematica "Giuseppe Peano", Universtità degli Studi di Torino, *Turin, Italy*, February 2016;

68. *Inverse problems in exploration and global seismology*, Computer, Electrical and Mathematical Science and Engineering Division, KAUST, *Saudi Arabia*, November 2016;

69. *Can we solve the seismic inverse problem?*, Department of Mathematics, University of Texas at Austin, *Austin, TX*, February 2017;

70. *On the spectrum of the earth*, Laboratoire Jean Kuntzmann, Université Grenoble Alpes, *Grenoble, France*, December 2017;

71. *Deep learning mitigating ill-posedness in seismic inverse problems*, Institute of Geophysics, China Earthquake Administration, *Beijing, China*, June 2018;

72. *Deep learning mitigating ill-posedness in seismic inverse problems*, School of Earth and Space Sciences, University of Science and Technology of China, *Hefei, China*, July 2018;

73. *Advances in computational seismology*, Institute for CyberScience, Penn State University, *State College, PA*, November 2018;

74. *Inverse problems in anisotropic elasticity and seismology*, Yau Mathematical Sciences Center, Tsinghua University, *Beijing, China*, June 2019;

75. *Globally injective (ReLU) neural networks*, Department of Mathematics, UCI, *Irvine, CA*, July 2020, virtual;

76. *Deep learning, inference and inverse problems*, School of Physical and Mathematical Sciences, Nanyang Technological University, *Singapore*, July 2021, virtual;

77. *Anatomy of Mars SEIS data from deep learning*, Machine Learning in Solid Earth Geoscience virtual lecture series, Los Alamos National Laboratory, *Los Alamos, NM*, July 2021, virtual;

78. *Perspectives on polyphonic signal identification, classification, source localization and geophysical forecasting with deep learning*, Division of Geological and Planetary Sciences, CalTech, *Pasadena, CA*, December 2021.

External research support

(vi) the consortium project on Seismic Inverse Methods for Complex Structures at the Center for Wave Phenomena (Colorado School of Mines), and (vii) Ph.D. scholarships from industry.

1997	–	Seismic inverse methods for complex structures (co-leader with N. Bleistein, K. Larner, J. Scales, I. Tsvankin)	consortium project $ 759,000
1997	–	unrestricted grant (*efficient one-way wave propagation*)	Mobil E&P Center $ 30,000
1998	–	Seismic inverse methods for complex structures (co-leader with N. Bleistein, K. Larner, J. Scales, I. Tsvankin)	consortium project $ 1,021,066
1998	– 1999	DuPont Educational Aid Program (*imaging-inversion in the presence of caustics*)	DuPont Central R&D $ 20,000
1998	– 2001	Ph.D. scholarship (*imaging-inversion in the presence of caustics*)	(BP)Amoco Norway tuition + stipend
1998	– 2001	Ph.D. scholarship (*generalized screen propagation and imaging*)	(TotalFina)Elf E&P tuition + stipend
1999	–	Seismic inverse methods for complex structures (co-leader with N. Bleistein, K. Larner, J. Scales, I. Tsvankin)	consortium project $ 791,166
2000	–	Seismic inverse methods for complex structures (co-leader with K. Larner, J. Scales, R. Snieder, I. Tsvankin)	consortium project $ 1,026,319
2001	–	Seismic inverse methods for complex structures (co-leader with K. Larner, J. Scales, R. Snieder, I. Tsvankin)	consortium project $ 973,500
2002	–	Seismic inverse methods for complex structures (co-leader with K. Larner, J. Scales, R. Snieder, I. Tsvankin)	consortium project $ 1,270,900

2002 – 2004	True-amplitude seismic imaging (PI with S.V. Goldin (Siberian Division of Russian Academy of Sciences)	CRDF (RG1-2362-NO-02) $ 75,000	
2002 – 2005	Ph.D. scholarship (*inverse multiple scattering*)	Total E&P $ 20,000/annum	
2003 –	Seismic inverse methods for complex structures (co-leader with K. Larner, R. Snieder, I. Tsvankin)	consortium project $ 1,377,763	
2004 –	Seismic inverse methods for complex structures (co-leader with K. Larner, R. Snieder, I. Tsvankin)	consortium project $ 1,010,000	

2004 – 2005	Anisotropy and mantle flow beneath Japan from seismological observations and geodynamical modeling (co-PI with R.D. van der Hilst, B.H. Hager (MIT))	NSF (EAR-0337697) $ 243,024
2004 – 2005	Ph.D. scholarship (*curvelet decomposition of seismic migration*)	Total E&P $ 20,000/annum
2004 – 2007	Multi-resolution lower mantle tomography (co-PI with R.D. van der Hilst (MIT))	NSF (EAR-0409816) $ 310,622
2004 – 2007	CMG: Development and application of inference methods for imaging neighborhoods of Earth's core-mantle boundary with broad-band ScS and SKKS coda waves (co-PI with R.D. van der Hilst (MIT), G. Uhlmann (UW), L. Tenorio (CSM))	NSF (EAR-0417891) $ 672,758
2007 –	Geo-Mathematical Imaging Group	industry project $ 400,000
2007 – 2010	CMG: Multi-scale (wave-equation) tomographic imaging with USArray waveform data (co-PI with R.D. van der Hilst (MIT), G. Uhlmann (UW), L. Tenorio (CSM), P. Ma (UIUC))	NSF (EAR-0757814/ DMS) $ 1,041,435

2008	– 2011	CSEDI: Multi-scale analysis of mantle discontinuities using inverse scattering of SS waves and experimental mineral physics (co-PI with R.D. van der Hilst (MIT), S.-H. Shim (MIT))	NSF (EAR-0724644) $ 271,199
2008	–	Geo-Mathematical Imaging Group	industry project $ 400,000
2009	– 2012	Stochastic and multiscale analysis of ambient-noise generated scattered waves and imaging of the earth (co-PI: K. Sølna (UCI))	NSF ARRA (DMS-0908274) $ 636,067
2009	–	Geo-Mathematical Imaging Group	industry project $ 400,000
2010	–	Geo-Mathematical Imaging Group	industry project $ 400,000
2010	– 2013	CMG: Nonlinear elastic-wave inverse scattering and tomography – from cracks to mantle convection (co-PI with R.D. van der Hilst (MIT), G. Uhlmann (UW), A. Vasy (Stanford))	NSF (DMS-1025318) $ 1,322,724
2011	–	Geo-Mathematical Imaging Group	industry project $ 480,000
2012	–	Geo-Mathematical Imaging Group	industry project $ 400,000
2013	–	Geo-Mathematical Imaging Group	industry project $ 400,000
2013	– 2015	industrial PostDoc	Total $ 170,000
2014	–	Geo-Mathematical Imaging Group	industry project $ 320,000

2015 – 2018	Inverse boundary value problems for scalar and elastic waves: Stability estimates and iterative reconstruction	NSF (DMS-1559587) $ 190,000	
2015 – 2018		Simons Foundation $ 975,000	
2016 – 2018	industrial PostDoc	Total $ 289,995	
2016 –	MATH + X Symposium on Seismology and Inverse Problems	Simons Foundation $ 81,450	
2016 –	Geo-Mathematical Imaging Group at Rice	industry project $ 160,000	
2017 –	MATH + X Symposium on Data Science and Inverse Problems in Geophysics	Simons Foundation $ 83,282	
2017 –	Geo-Mathematical Imaging Group at Rice	industry project $ 320,000	
2018 –	MATH + X Symposium on Inverse Problems and Deep Learning in Space Exploration	Simons Foundation $ 99,693	
2018 – 2022	Seismology- and geodesy-based inverse problems crossing scales, with scattering, anisotropy and nonlinear elasticity	NSF (DMS-1815143) $ 319,999	
2018 – 2021		Simons Foundation $ 1,170,000	
2018 – 2020	industrial PostDoc	Total $ 295,608	
2018 –	Geo-Mathematical Imaging Group at Rice	industry project $ 240,000	
2019 –	MATH + X Symposium on Inverse Problems and Deep Learning, Mitigating Natural Hazards	Simons Foundation $ 102,082	

2019	–	Geo-Mathematical Imaging Group at Rice	industry project $ 240,000
2019	– 2022	Deep learning for forecasting of fracture and fault evolution (co-PI: R. Baraniuk (Rice))	DOE (DE-SC0020345) $ 775,000
2020	–	MATH + X Symposium on Matter under Extreme Conditions in Solar Giants and Exoplanets, Inverse Problems and Deep Learning	Simons Foundation $ 102,541
2020	–	Geo-Mathematical Imaging Group at Rice	industry project $ 240,000
2020	–	unrestricted gift	Google $ 10,000
2021	–	Geo-Mathematical Imaging Group at Rice	industry project $ 160,000
2021	– 2024	Recovery of material parameters using, and friction laws associated with earthquakes, interseismic slip and tidal deformation	NSF (DMS-2108175) $ 208,000

Last update

10th February 2022