

# Dr. Arick Shao

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**Employment** **Reader in Mathematics:** Queen Mary University of London, *2023–present*  
**Senior Lecturer in Mathematics:** Queen Mary University of London, *2018–2023*  
**Lecturer in Mathematics:** Queen Mary University of London, *2016–2018*  
**Research Associate:** Imperial College London, *2014–2016*  
**Postdoctoral fellow:** University of Toronto, *2011–2014*

**Education** **Ph.D., Mathematics:** Princeton University, *2010*  
*Breakdown Criteria for Nonvacuum Einstein Equations*  
Supervisor: Sergiu Klainerman  
**B.S., Mathematics, Computer Science:** University of Texas at Austin, *2004*

**Research** Analysis, partial differential equations  
Dispersive, hyperbolic, and wave equations  
Differential geometry, mathematical relativity  
Riemannian and Lorentzian geometry, geometric PDE, Einstein equations

**Awards** *STFC Standard Grant*  
Title: *Astronomy at Queen Mary 2023–2026* (ST/X000931/1)  
Project: *Early Universe Cosmology Beyond General Relativity* (co-investigator)  
Duration: *2023–2026*  
*Geometry, Relativity and Partial Differential Equations*  
Mini-CDT (Centre for Doctoral Training) funded by Faculty of Science and Engineering, QMUL  
Duration: *2020–2022*  
*EPSRC First Grant*  
Project: *Unique Continuation for Geometric Wave Equations, and Applications to Relativity, Holography, and Controllability* (EP/R011982/1)  
Duration: *2018–2020*  
Funding amount: GBP 100,891  
*Awarded special mention for Research Contributions*  
Recognition for research accomplishments at Queen Mary University of London, *winter 2018*  
*Faculty of Natural Sciences Prize for Excellence in the Support of Teaching and Learning*  
Award for teaching assistants at Imperial College London, *spring 2015*

*Research Impulse Platform Grant*

Funding awarded by Imperial College London for conference travel, *spring 2015*

## Supervision

*Postdoctoral Researchers*

Vaibhav Jena, EPSRC Postdoctoral Researcher, *2021–2022*

*PhD Students* (as 1st supervisor)

Simon Guisset, *2020–present*

Alexander McGill, *2018–2022*

Vaibhav Jena, *2017–2021*

*MSc Projects*

*Controllability of Differential Equations*

Nirujan Sarvanantharajah, *summer 2022*

*Fourier Space Methods for PDEs*

Laura Risley, *2019–20*

*3rd-Year Undergraduate Projects*

*Higher-Dimensional Manifolds*

Jordan Marajh, *spring 2021*

*Classical Curve and Surface Geometry*

Sajni Parbat Kerai, *fall 2022*

Feiza Ahmed, *spring 2022*

Naia Briscall, *spring 2021*

*Fourier Transformations and Applications*

Luke Reid, *spring 2023*

Sarwan Singh Jandu, *fall 2022*

Mohammed Nazim Turker, *fall 2021*

Ozora Gunaseelan, Wajidur Rahman, *spring 2020*

*Calculus of Variations*

Brandon Dewaan James, *spring 2021*

Sasha Owen, *spring 2020*

*Controllability of Differential Equations*

Oluwaseun Oladeji, *spring 2023*

John Priestman, *spring 2021*

Mohamed Sharif-Eidarus, *fall 2019*

*Integral Theorems in Differential Geometry*

Melissa Doci, *spring 2021*

Vishnuka Jeyarathnam, Lauren Sealey, *fall 2019*

*Applications of harmonic analysis to PDEs*

Ousama Mahomed, *spring 2018*

*Wave Equations*

Ervig Hysaj, *spring 2018*

Kyriacos Patatakos, *spring 2017*

*Summer Research Projects*

*Viscous Relativistic Hydrodynamics* (with Shabnam Beheshti), QMUL

Jordan Marajh, Summer Research Internships for BAME Undergraduate Students, *summer 2021*.

Denis Mih, LMS Undergraduate Bursary, *summer 2021*.

*Uniqueness in Wave Equations*, Imperial College London

Quintin Luong, Undergraduate Research Opportunies, *summer 2016*.

*Nonlinear Wave Equations*, Imperial College London

Chun Hong (Anfernee) Lo, Undergraduate Research Opportunies, *summer*

2015.

## Teaching

*MTH5113: Introduction to Differential Geometry*

Lecturer and module creator, Queen Mary University of London, *spring 2023, spring 2022, spring 2021, spring 2020, spring 2019*

*MTH5109: Geometry II: Knots and Surfaces*

Lecturer, Queen Mary University of London, *fall 2017, fall 2016*

*M4P41: Analytic Methods in PDEs*

Lecturer, Imperial College London, *spring 2016*

*Dispersive Equations (TCC)*

Lecturer, Imperial College London, Mathematics Taught Course Centre, *fall 2015*

*M3P7: Functional Analysis*

Teaching assistant, Imperial College London, *spring 2015*

*MAT336: Elements of Analysis*

Instructor, University of Toronto, *spring 2014*

*MAT244: Ordinary Differential Equations*

Instructor, University of Toronto, *spring 2014*

*MAT334: Complex Variables*

Instructor, University of Toronto, *spring 2013, fall 2012*

*MAT235: Calculus for Life Sciences II*

Instructor, University of Toronto, *spring 2012, fall 2011*

## Community

Co-organizer, *London PDE Seminar*

Queen Mary University of London, Imperial College London, University College London, *2021–present*

Co-organizer, *QMUL/ICL Reading Seminar*

Queen Mary University of London, Imperial College London, *2020–present*

*Undergraduate Student Exam Board Chair*

Queen Mary University of London, *2020–present*

Organizer, *Mini-Workshop on Wave Equations*

Queen Mary University of London, *Jan. 2020*

Co-organizer, *Geometry and Analysis Seminar*

Queen Mary University of London, *2017–2020*

Co-organizer, *Geometry and Analysis Reading Seminar*

Queen Mary University of London, *2017–2019*

Co-organizer, *Bag Lunch Educational Seminar*

Queen Mary University of London, *2017–2018*

Co-organizer, *Workshop on Geometric Hyperbolic PDE*

Imperial College London, *Sept.–Oct. 2015*

Postdoc representative, Department of Mathematics

Imperial College London, *2015–2016*

Co-organizer, *Analysis and Applied Math Seminar*

University of Toronto, *2012–2014*

## Invited Talks

- Control of parabolic equations with inverse square infinite potential wells*  
IWOTA 2023, Spectral Inequalities and Null-Controllability (special session)  
*Aug. 2023*  
Analysis and PDE Seminar, SUSTech International Center for Mathematics  
*Jun. 2023*  
Ghent Methusalem Junior Seminar, Ghent University *May. 2023*  
London Analysis and Probability Seminar, *Apr. 2023*  
Geometric Aspects of Evolution and Control, FernUniversität Hagen, *Apr. 2023*
- Bulk-boundary correspondence for vacuum asymptotically Anti-de Sitter spacetimes*  
Topics in General Relativity, University of Münster, *July 2023*  
Conference on Nonlinear Waves and Mathematical General Relativity, Tsinghua University, *July 2023*  
Seminar in Mathematical General Relativity, LJLL, Sorbonne Université, *May. 2023*  
Princeton Gravity Initiative Seminar, Princeton University, *Oct. 2022*  
Hyperbolic Differential Equations in Geometry and Physics, MATRIX, *Apr. 2022*  
CMSA General Relativity Seminar, Harvard University, *Mar. 2022*  
Geometric Analysis and Partial Differential Equations Seminar, University of Cambridge, *Jan. 2022*  
2021 Geometric Analysis and Hyperbolic PDE Conference, Guangxi Center for Mathematical Research, *Dec. 2021*
- Extension of symmetries from conformal boundaries of vacuum asymptotically AdS spacetimes*  
2020 Geometric Analysis and Hyperbolic PDE Conference, Guangxi Center for Mathematical Research, *Dec. 2020*  
GR and Hyperbolic PDE Seminar, Princeton (online), *December 2020*  
Relativity Seminar, Universität Wien, *November 2020*
- Correspondence and rigidity results on asymptotically anti-de Sitter spacetimes*  
Time-like Boundaries in General Relativistic Evolution Problems, BIRS-CMO (Oaxaca), *August 2019*  
Relativistic Mathematical Physics in Grenoble, Institut Fourier (Université Grenoble Alpes), *May 2019*  
Mathematical Relativity Seminar, IST (Universidade de Lisboa), *Sept. 2018*  
International Conference on Nonlinear Waves and General Relativity, Chinese University of Hong Kong, *Dec. 2017*  
Workshop on General Relativity and AdS/CFT, Fields Institute, *Oct. 2017*
- On controllability of waves and geometric Carleman estimates*  
Webinar on PDEs and Related Areas, IIT-Kanpur, *Dec. 2020*  
CRM-Montreal-Quebec Analysis Seminar, *Oct. 2020*  
Séminaire EDP et Physique Mathématique, LAGA, Université Paris-XIII, *May. 2020*  
2019 International Conference on Geometric Analysis and Hyperbolic Equations, Guangxi Center for Mathematical Research, *Dec. 2019*  
London Mathematical Society Hyperbolic Network Meeting, Loughborough University, *Mar. 2019*  
Séminaire Laurent Schwartz, IHES, *Feb. 2019*  
NCTS Seminar, NCTS (National Taiwan University), *Dec. 2018*  
Geometry and Analysis Seminar, University of Oxford, *Oct. 2018*

- Analysis and Geometry Seminar, University of Bristol, *Mar. 2018*
- Uniqueness theorems for waves, Carleman estimates, and applications*  
Analysis and Applications Seminar, University of Leeds, *Feb. 2018*
- Uniqueness theorems for waves from infinity, and applications*  
Analysis Seminar, Cardiff University, *Jan. 2017*  
Analysis Seminar, University of Edinburgh, *Nov. 2015*  
Analysis Seminar, Kings College London, *Nov. 2015*  
100 Years of General Relativity, Workshop on Nonlinear Wave Equations, Fields Institute, *Jun. 2015*  
Junior Warwick-Imperial-Cambridge Seminar, London, *Dec. 2014* (short talk)
- Uniqueness theorems on asymptotically Anti-de Sitter spacetimes*  
Seminar on Mathematical General Relativity, UPMC, IHES, *Jul. 2017*  
2016-17 Warwick EPSRC Symposium: Geometric PDEs, University of Warwick, *Dec. 2016*  
Geometry and Analysis Seminar, Queen Mary University of London, *Oct. 2016*  
London Analysis and Probability Seminar, *Oct. 2016*
- Unique continuation from infinity, Carleman estimates, and applications*  
Workshop on Carleman Estimates, Unique Continuation, and Applications, University College London, *Nov. 2016*
- Correspondence properties for waves on asymptotically Anti-de Sitter spacetimes*  
Gravity Seminar, University of Southampton, *Nov. 2015*
- Unique continuation for massive waves in asymptotically Anti-de Sitter spacetimes*  
100 Years of General Relativity, Workshop on Black Hole Stability, Fields Institute, *Jun. 2015*  
Equadiff 2015, Minisymposium on Mathematical Problems of General Relativity, *Jul. 2015* (short talk)
- Unique continuation, Carleman estimates, and blow-up for nonlinear waves*  
Partial Differential Equations Seminar, Oxford University, *Feb. 2015*
- Unique continuation from infinity for linear waves*  
Geometry and Analysis Seminar, Imperial College London, *Nov. 2014*  
Seminar of Analysis and Applications, EPFL, *Nov. 2014*  
Geometric Analysis and PDE Seminar, Cambridge University, *Oct. 2014*  
Analysis and PDEs Seminar, Imperial College London, *Oct. 2014*  
Analysis Seminar, University of Warwick, *Oct. 2014*  
Seminar on Mathematical General Relativity, Université Pierre et Marie Curie, *Sept. 2014*  
Geometric Analysis Colloquium, Fields Institute, *Dec. 2013*
- Null cones to infinity, curvature flux, and Bondi mass*  
Conference on Nonlinear Wave Equations, IHP, *May 2013*  
Seminar on Mathematical General Relativity, Université Pierre et Marie Curie, *Jan. 2013*  
Analysis and Applied Math Seminar, University of Toronto, *Oct. 2012*  
Workshop in *Evolution equations of physics, fluids, and geometry*, BIRS (Banff), *Sept. 2012*  
Workshop in *Mathematical aspects of general relativity*, MFO (Oberwolfach), *Jul. 2012* (short talk)
- A representation formula for tensor wave equations on curved spacetimes*

Fields Analysis Working Group, Fields Institute, *Mar. 2012*

*Breakdown criteria for nonvacuum Einstein equations*

Analysis and Applied Math Seminar, University of Toronto, *Oct. 2011*

2010 Joint Mathematics Meetings, *Jan. 2010* (short talk)

Analysis Seminar, Princeton University, *Dec. 2009*

## Outreach

Speaker, Wonderful World of Maths (Taster Event), *December 2022, March 2023*

Event introducing A-level students to university mathematics.

Title: *My infinity is bigger than your infinity*

Volunteer, I'm a Mathematician, *summer 2020*

Online chats with school classes and youth groups in the UK.

Academic speaker, Year 11 Maths Summer School, *summer 2018*

Week-long summer school for year 11 students interested in mathematics

Gave taster lecture (title: *Why my infinity is bigger than your infinity*)

Academic consultant, Year 11 Maths Summer School, *summer 2017*

Week-long summer school for year 11 students interested in mathematics

Developed lecture and project material (topic: waves, sound waves)

Speaker, University of London Taster Day, *April 2017*

Event with brief taster lectures for year 12 students.

Title: *The Mathematics Behind Einstein's Theory of Relativity*

Plenary speaker, Warwick Imperial Spring Meeting, *spring 2016*

Conference for upper-year undergraduate, master's, and early-year PhD students.

Title: *A Brief Introduction to Mathematical Relativity*

Postdoc Pizza Seminar, Imperial College London, *fall 2014*

Title: *Introduction to Mathematical General Relativity*

Math Mentorship Program, *spring 2012*

Mentor for local high school students

Science Rendezvous, volunteer, *May 2012*

Festival at Canadian universities for promoting science and mathematics to public

## Publications

### Preprints and Submitted Papers

1. S. Guisset, A. Shao, *On counterexamples to unique continuation for critically singular wave equations*, (2023)  
arXiv: <http://www.arxiv.org/abs/2308.03525>
2. A. Enciso, A. Shao, B. Vergara, *Controllability of parabolic equations with inverse square infinite potential wells via global Carleman estimates*, (2023)  
arXiv: <http://www.arxiv.org/abs/2112.04457>
3. V. K. Jena, A. Shao, *Control of waves on Lorentzian manifolds with curvature bounds*, (2021)  
arXiv: <http://www.arxiv.org/abs/2112.09539>

### Accepted and Published Papers

1. G. Holzegel, A. Shao, *The bulk-boundary correspondence for the Einstein equations in asymptotically Anti-de Sitter spacetimes*, Arch. Ration. Mech. Anal., 247 (2023), 56  
arXiv: <http://www.arxiv.org/abs/2207.14217>
2. L. D. Cha, A. Shao, *Global stability of traveling waves for  $(1 + 1)$ -dimensional systems of quasilinear wave equations*, J. Hyperbol. Differ. Eq., 19 (2022), 549–586  
arXiv: <http://www.arxiv.org/abs/2008.09991>
3. A. Chatzikaleas, A. Shao, *A gauge-invariant unique continuation criterion for waves in asymptotically Anti-de Sitter spacetimes*, Commun. Math. Phys. 395 (2022), 521–570  
arXiv: <http://www.arxiv.org/abs/2201.06010>
4. A. Enciso, A. Shao, B. Vergara, *Carleman estimates with sharp weights and boundary observability for wave operators with critically singular potentials*, J. Eur. Math. Soc. 23 (2021), 3459–3495  
arXiv: <http://www.arxiv.org/abs/1902.00068>
5. A. McGill, A. Shao, *Null Geodesics and Improved Unique Continuation for Waves in Asymptotically Anti-de Sitter Spacetimes*, Class. Quantum Grav., 38 (2020), 054001  
arXiv: <http://www.arxiv.org/abs/2008.07416>
6. A. Shao, *The Near-Boundary Geometry of Einstein-Vacuum Asymptotically Anti-de Sitter Spacetimes*, Class. Quantum Grav., 38 (2020), 034001  
arXiv: <http://www.arxiv.org/abs/2008.07396>
7. A. Shao, *On Carleman and observability estimates for wave equations on time-dependent domains*, Proc. Lond. Math. Soc., 119 (2019)  
arXiv: <http://www.arxiv.org/abs/1805.07859>
8. G. Holzegel, A. Shao, *Unique continuation from infinity in asymptotically Anti-de Sitter spacetimes II: Non-static boundaries*, Comm. Partial Differential Equations, 42 (2017), 1871–1922  
arXiv: <http://www.arxiv.org/abs/1608.07521>
9. G. Holzegel, A. Shao, *Unique continuation from infinity in asymptotically Anti-de Sitter spacetimes*, Commun. Math. Phys., 347 (2016), 1–53  
arXiv: <http://www.arxiv.org/abs/1508.03820>
10. S. Alexakis, A. Shao, *On the profile of energy concentration for subconformal focusing nonlinear waves*, Trans. Amer. Math. Soc., 369 (2017), 5525–5542  
arXiv: <http://www.arxiv.org/abs/1412.6844>

11. S. Alexakis, A. Shao, *Global uniqueness theorems for linear and nonlinear waves*, J. Funct. Anal., 269 (2015), 3458–3499  
arXiv: <http://www.arxiv.org/abs/1412.1537>
12. S. Alexakis, V. Schlue, A. Shao, *Unique continuation from infinity for linear waves*, Adv. Math., 286 (2016), 481–544  
arXiv: <http://www.arxiv.org/abs/1312.1989>
13. S. Alexakis, A. Shao, *Bounds on the Bondi energy and momentum by the flux of curvature*, J. Eur. Math. Soc., 18 (2016), 2045–2106  
arXiv: <http://www.arxiv.org/abs/1308.4170>
14. S. Alexakis, A. Shao, *On the geometry of null cones to infinity under curvature flux bounds*, Class. Quantum Grav., 31 (2014) 195012  
arXiv: <http://www.arxiv.org/abs/1303.1260>
15. D. Egli, J. Fröhlich, Z. Gang, A. Shao, I.M. Sigal, *Hamiltonian dynamics of a particle interacting with a wave field*, Comm. Partial Differential Equations, 38 (2013), 2155–2198  
arXiv: <http://www.arxiv.org/abs/1211.6154>
16. A. Shao, *New tensorial estimates in Besov spaces for time-dependent  $(2 + 1)$ -dimensional problems*, J. Hyperbol. Differ. Eq., 11 (2014), 821–908  
arXiv: <http://www.arxiv.org/abs/1202.1295>
17. A. Shao, *On breakdown criteria for nonvacuum Einstein equations*, Annales Henri Poincaré, 12 (2011), 205–277  
arXiv: <http://www.arxiv.org/abs/1008.1605>
18. A. Shao, *A generalized representation formula for systems of tensor wave equations*, Commun. Math. Phys., 306 (2011), 51–82  
arXiv: <http://www.arxiv.org/abs/1005.4509>

## Seminar Proceedings

1. A. Shao, *Control of parabolic equations with inverse square infinite potential wells*, Ghent Analysis Center, Research Perspectives (to appear, 2024)
2. A. Shao, *Bulk-boundary correspondences and unique continuation in asymptotically anti-de Sitter spacetimes*, MATRIX Annals (to appear, 2023)
3. A. Shao, *On controllability of waves and geometric Carleman estimates*, Séminaire Laurent Schwartz — EDP et applications, (2018–2019)

## Dissertation

1. A. Shao, *Breakdown Criteria for Nonvacuum Einstein Equations*, PhD thesis, Princeton University, Jun. 2010