

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 *EPSRC Small Grant*
Project: *Rigidity Problems in Holography and Relativity* (EP/Y021487/1)
Duration: *2024*
Funding amount: GBP 77,733
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

Abrar Almahmeed, *summer 2023*

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 Opportunities, *summer 2016*.
Nonlinear Wave Equations, Imperial College London
Chun Hong (Anfernee) Lo, Undergraduate Research Opportunities, *summer 2015*.

Teaching

SEF015: Discrete Mathematics
Co-lecturer, Queen Mary University of London, *spring 2024*

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, *2020–2022*

Undergraduate Student Exam Board Chair
Queen Mary University of London, *2020–2023*

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

Seminar in Control, LJLL, Sorbonne Université, *Jan. 2024*

Analysis and PDE Seminar, Donghua University *Nov. 2023*

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

Sanya Waves, Tsinghua Sanya International Mathematics Forum, *Jan. 2024*

Mathematical GR and Hyperbolic PDE Seminar, Columbia University, *Oct. 2023*

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), *Aug. 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. A. Shao, B. Vergara, *Approximate boundary controllability for parabolic equations with inverse square infinite potential wells*, (2023)
arXiv: <http://www.arxiv.org/abs/2311.01628>
2. S. Guisset, A. Shao, *On counterexamples to unique continuation for critically singular wave equations*, (2023)
arXiv: <http://www.arxiv.org/abs/2308.03525>
3. 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>
4. 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, (2021–2022)
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