Dr. Payel Mukhopadhyay

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Research Interests

I work on complex dynamical systems, with a focus on continuum dynamics and transport phenomena: turbulence, instabilities, mixing, shocks, and multiscale structure. These systems are computationally expensive to simulate, hard to probe experimentally, and poorly understood across various scientific settings. I develop AI-based, computational, and theoretical methods to study them - building models that accelerate simulations, aid physical interpretation, and open new routes to scientific discovery. My research includes (non-exhaustive list):

- **Methods:** scientific foundation models, surrogate modelling and neural operators, generative and probabilistic models, mechanistic interpretability, semi-analytical theory, data-efficient and multi-fidelity learning.
- **Scientific themes:** generalisation and transfer across physical regimes, simulation-to-experiment transfer, low-data adaptation, physical diagnostics, interpretable structure in learned representations.
- **Application domains:** hydrodynamic instabilities (Rayleigh–Taylor, Kelvin–Helmholtz, etc.), turbulent mixing and transport, astrophysical fluid outflows, compact-object environments (neutron star mergers, supernovae), neutrino astrophysics, cosmic-ray transport, laboratory experiments in continuum and transport-dominated systems.

Experience

Assistant Research Professor May 1, 2025–now
University of Cambridge

- Recipient of Physics-AI fellow award, DAMTP & Infosys–Cambridge AI Centre, 2025.
- Leading efforts on building and applying foundation models to scientific data at Cambridge and Polymathic AI.
- Supervision of PhD and MPhil students.

Neutrino Theory Network research fellowship Oct 30, 2022–May 1 2025
UC Berkeley, CA, USA. Awarded independent research grant of 300K USD.

- November 2024–present: Full member of Polymathic AI collaboration.
- Student mentoring.

Education

Ph.D. in theoretical & computational astrophysics, GPA: 4.06/4. Highest possible grade.
Sep 20, 2017–Sep 29, 2022
Stanford University

- **P. Mukhopadhyay**, "Neutrino driven outflows in supernovae : from hydrodynamics to nucleosynthesis", Stanford University, thesis.

B.S.-M.S Dual degree, CGPA: 9.55/10.0. Rank: 2/120. 2012–2017
Indian Institute of Science Education and Research (IISER), India.

- Master's thesis in mathematical Physics: Carter's Constant and a New Look at Superintegrability

Peer-reviewed and In-submission papers

▶ *Denotes Alphabetical author order (convention in the corresponding field). For alphabetical listing papers, the lead author is denoted by †.*
** Indicates PhD student to whom I provided primary research advising.*
(ML conferences post an official acceptance rate. For such papers, the acceptance rate is noted.)
Bibliographic metrics: 500+ citations, h-index: 9. Automatically updated in Google Scholar.

1. **P. Mukhopadhyay**, Stefan Nixon, Romain Watteaux, (+17 authors), Stuart B. Dalziel, Miles Cranmer. "Emergent transfer of a physics foundation model from simulation to laboratory turbulence". *Under submission.* arxiv: 2606.01470. June 2026.

2. Cristiana Diaconu*, M. Cranmer, R. Turner, T. Marwah & **P. Mukhopadhyay**, "Probabilistic Retrofitting of Learned Simulators". *accepted at ICML 2026.* 26% acceptance rate.

   Also published in *ICLR 2026 AI & PDE Workshop*.

3. Hadi Sotoudeh*, **P. Mukhopadhyay**, R. Ohana, M. McCabe, N. Lawrence, S. Ho, M. Cranmer, "On the Value of Tokeniser Pretraining in Physics Foundation Models"; *ICLR 2026 AI & PDE Workshop*.

4. **P. Mukhopadhyay**, Michael Mccabe, R. Ohana, Miles Cranmer, "Overtone: Cyclic Patch Modulation for Clean, Efficient, and Flexible Physics Emulators"; *International Conference on Learning Representations, ICLR 2026*. (26% acceptance rate)

5. Michael Mccabe, **P. Mukhopadhyay**, T. Marwah, et al., "Walrus: A Cross-Domain Foundation Model for Continuum Dynamics". *accepted as ICML 2026 spotlight paper.* arXiv preprint here. ∼2.6% acceptance rate.

6. Rio Fear*, **P. Mukhopadhyay**, M. Mccabe, A. Bietti, M Cranmer, "Physics Steering: Causal Control of Cross-Domain Concepts in a Physics Foundation Model". *Mechanistic Interpretability Workshop (NeurIPS 2025).*

7. **Polymathic AI** (incl. P. Mukhopadhyay); "Predicting partially observable dynamical systems via diffusion models with a multiscale inference scheme", in *The Thirty-ninth Annual Conference on Neural Information Processing Systems, NeurIPS 2025*. (25% acceptance rate)

8. **Polymathic AI** (incl. P. Mukhopadhyay); "AION-1: Omnimodal foundation model for astronomical sciences", in *The Thirty-ninth Annual Conference on Neural Information Processing Systems, NeurIPS 2025*. (25% acceptance rate)

9. **P. Mukhopadhyay**, M. Mccabe, R. Ohana, M. Cranmer, "Compute-Adaptive Surrogate Modeling of Partial Differential Equations". *International Conference on Learning Representations, ICLR 2025, Machine Learning Multiscale Physics workshop.*

10. K. Lund, **P. Mukhopadhyay**, J. Miller, G. McLaughlin, "Angle-dependent in situ fast flavor transformations in post-neutron-star-merger disks". *The Astrophysical Journal Letters, Volume 985, Number 1, 2025*.

11. **Polymathic AI** (incl. P. Mukhopadhyay); "The Well: A large-scale collection of diverse physics simulations for machine learning", in *The Thirty-eight Conference on Neural Information Processing Systems Datasets and Benchmarks Track, NeurIPS 2024*. (25% acceptance rate)

12. **P. Mukhopadhyay**, J. Miller, G. McLaughlin, "The time evolution of fast flavor crossings in post-merger disks around a black hole remnant". *Astrophys.J. 974 (2024)*.

▶ 13. A. Friedland, **P. Mukhopadhyay**†, A. Patwardhan, "Successful νp-process in neutrino-driven outflows in core-collapse supernovae". *JCAP* **02** (2025) 005.

14. **P. Mukhopadhyay**, E. Peretti, N. Globus, P. Simeon and R. Blandford, "Cosmic-Ray re-acceleration at galactic wind termination shock", *The Astrophysical Journal, 953, 1 (2023)*.

15. **P. Mukhopadhyay**, T. Linden, "Self-Generated Cosmic-Ray Turbulence Can Explain the Morphology of TeV Halos", *Phys.Rev.D 105 (2022) 12, 123008*.

▶ 16. A. Friedland, **P. Mukhopadhyay**†, "Near-critical supernova outflows and their neutrino signatures", *Phys.Lett.B, 834, 137403 (2022)*.

▶ 17. R. K. Leane, T. Linden, **P. Mukhopadhyay**†, N. Toro, "Celestial-Body Focused Dark Matter Annihilation Throughout the Galaxy", *Phys. Rev. D, 103, 075030 (2021)*.

18. **P. Mukhopadhyay**, R. K. Nayak, "Carter Constant and Superintegrability". *International Journal Of Modern Physics D (2018)*.

19. **P. Mukhopadhyay**, J. S. Bielich, "Quark stars admixed with dark matter". *Phys. Rev. D, 93, 083009 (2016)*.

Press Releases

- New AI models trained on physics, not words, are driving scientific discovery; Cambridge University press release. Based on the Walrus paper, led by M McCabe, **P Mukhopadhyay** et al, and the Polymathic AI team.
- New datasets will train AI models to think like scientists; Cambridge University press release. Large scale dataset building and benchmarking effort with **P Mukhopadhyay** as a central contributor within the Polymathic AI team.

Research Advising

- Shoaib Jamal Shamsi, Master student in High Performance Computing, International Center for Theoretical Physics, ICTP, Trieste, Italy.
- Haaris Mian - intern at Polymathic AI.
- Cristiana Diaconu - 2nd year PhD student at Cambridge, intern at Polymathic AI (see paper above)
- Hadi Sotoudeh - 2nd Year PhD student, University of Cambridge (see paper above)
- Rio Fear - 2nd Year PhD student, University of Cambridge (see paper above)
- Urvi Nath - MPhil in Data Intensive Science, Cambridge
- Bien-Aime Makimona Kiakisolako - MPhil in Data Intensive Science, Cambridge
- Cameron McCormack- MPhil in Data Intensive Science, Cambridge
- Hartej Soin- MPhil in Data Intensive Science, Cambridge
- Shuo Xin (Graduate student, SLAC, Stanford)
- Kelvin Lam (3rd year undergraduate, UC Berkeley, now a graduate student at UIUC)

Honors, Awards, and Computing Allocations

- Co-I, 10,000 GPU-hour compute allocation on Isambard-AI for: *PolymathicAI: Benchmarking and Prototyping Scientific Foundation Models* 2026
- Physics-AI fellowship, 3–year independent funding, DAMTP & Infosys–Cambridge AI Centre 2025
- **Neutrino Theory Network** fellowship (∼ USD 300K for 3 years) 2022
- **N3AS** postdoctoral fellowship (∼ USD 300K for 3 years) 2022, declined
- **Knoller fellowship** (University of Michigan) 2017, declined
- **Distinguished University fellowship** (Ohio State University) 2017, declined
- **SN Bose fellowship** (Penn State University, USA) 2016
- **DAAD-WISE scholarship** (Goethe University, Frankfurt, Germany) 2015
- **DST-INSPIRE scholarship** for undergraduate studies. Fully funded undergraduate education provided to students scoring in the top 1% across India in nationwide high school exam. 2012

Scientific presentations

- Invited talk. Trillium Technologies, Popcorn session on “Meet Walrus". 2026
- Invited talk. Sandia National Laboratory. 2026.
- Talk, *AI for accelerating Scientific Discovery*, Infosys-Cambridge AI Industry Symposium, a day connecting academic and industry perspectives on where AI is heading. 2026
- Invited talk. digiLab software company, Exeter, UK. 2026.
- Invited talk, Invitations to Industry (i2i) Seminar, The ERDŐS Institute, 2026.
- Departmental Seminar, Data Intensive Science (DIS) Seminar Series, DAMTP, Cambridge, 2026.
- Invited talk, D2MMS Virtual Seminar Series, Indian Institute of Technology (Indian School of Mines) Dhanbad, India, 2026.
- Collaboration-wide talk, Polymathic AI, 2026.
- Invited lecturer, Advanced School on Foundation Models for Scientific Discovery, International Centre for Theoretical Physics (Trieste, Italy), 2025. Cco-organized by ICTP alongside SISSA/TSDS, IBM and AREA.
- Collaboration-wide talk, Polymathic AI, 2025.
- Collaboration-wide talk, Polymathic AI, 2024.
- Invited talk, TU Darmstadt, 2023.
- Invited talk, Institute of Nuclear Theory, Seattle, 2023.
- Invited talk, N3AS Network, UC Berkeley, 2023.
- Talk, Plenary Session, Neutrino Theory Network Workshop, 2022.
- Invited talk, Ohio State University, 2021.
- Invited talk, New Directions in Neutrino Flavor Evolution in Astrophysical Systems, Institute of Nuclear Theory, Seattle, 2021.
- Invited talk, Dark Matter Forum, TRIUMF, Canada’s particle Accelerator Center, 2021.
- Invited talk, Ohio State University Seminar, 2021.
- Seminar, SLAC Theory Group, 2021.

- Talk, KIPAC Tea, Stanford, 2021.
- Talk, EPP Journal Club, Stanford Linear Accelerator Center, 2021.
- Talk, Americal Physical Society, Division of Particles and Fields, 2021.
- Talk, Phenomenology, Pittsburgh, PA, 2021.
- Talk, EuCAPT Annual Symposium, CERN, 2021.
- Invited talk, Saha Institute of Nuclear Physics, India, 2020.
- Invited talk, Mini Workshop on Neutrino Theory, Fermilab, 2020.
- Invited talk, Deep Underground Neutrino Experiment (DUNE) Collaboration Meeting, 2020.
- Invited talk, Deep Underground Neutrino Experiment (DUNE) Experimental Group, 2020.
- Invited talk, Institute of Nuclear Theory, Seattle, 2020.
- Talk, Phenomenology, Pittsburgh, PA, 2020.
- Talk, Americal Physical Society, 2020.
- Talk, Precision Investigations of the Neutrino Sector (PINS), 2019.
- Invited talk, Deep Underground Neutrino Experiment (DUNE) Collaboration Meeting, 2019.

Service

Reviewing

- Machine learning conferences and workshops: NeurIPS 2025, NeurIPS 2026; ICML 2025, ICML 2026; ICML AI & PDE Workshop 2026; ICLR Workshop on Machine Learning for Multiscale Processes 2025.
- Journals: Nature Machine Intelligence, The Astrophysical Journal.

Teaching experience

- Invited lecturer (Designed 1 lecture on foundation models + 1 tutorial session). Advanced School on Foundation Models for Scientific Discovery. International Centre for Theoretical Physics, Trieste, Italy (Sponsored by IBM), 2025. Cohort of 30 students who were early-career researchers and PhD students.
- Deep Learning instructor, Infosys industry training workshop, University of Cambridge, 2025. Approximately 50 participants, mostly Infosys employees.
- Deep Learning instructor, Infosys industry training workshop, University of Cambridge, 2024. Approximately 50 participants, mostly Infosys employees.
- Teaching assistant, Stanford University, Physics 45, Light and Heat (2018, 2019).
- Teaching assistant, Stanford University, Physics 212, Statistical Mechanics (2020).

Outreach

- Stanford Physics, Identity, and Equity (PIE) Program. Gave talks to encourage undergraduate students from underrepresented groups to join graduate school in Physics (Oct, 2021).