

# SAMSUZZAMAN AFROZ

*PhD Researcher in Gravitational-Wave Astrophysics and Cosmology*

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## Education

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|---|-----------------------------|
| <b>PhD in Gravitational-Wave Astrophysics &amp; Cosmology</b> | <b>2022–2027 (expected)</b> |
| Tata Institute of Fundamental Research (TIFR), Mumbai, India  |                             |
| <b>M.Sc. in Physics</b>                                       | <b>2020–2022</b>            |
| Presidency University, Kolkata, India                         |                             |
| <b>B.Sc. (Hons) in Physics</b>                                | <b>2017–2020</b>            |
| Jamia Millia Islamia, New Delhi, India                        |                             |

## Research Interests

Gravitational-wave astrophysics and cosmology; tests of General Relativity in weak- and strong-field regimes; compact binary populations and formation channels; multimessenger cosmology with standard sirens; dark energy and cosmological parameter inference; phase-space methods for gravitational-wave source classification; dark matter and exotic compact objects.

## Research Experience

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|---|--------------------------------|
| <b>Tata Institute of Fundamental Research (TIFR), Mumbai, India</b> | <b>January 2023 – Present</b>  |
| <i>PhD Research Student</i>   | Advisor: Dr. Suvodip Mukherjee |

- **Gravitational-Wave Astronomy:** Analyzed compact binary coalescence data from LIGO–Virgo–KAGRA to study binary black hole populations, formation channels, and their redshift evolution.
- **Multimessenger Cosmology:** Investigated constraints on the Hubble constant and the dark energy equation of state using bright and dark gravitational-wave standard sirens, in combination with electromagnetic surveys.
- **Phase-Space Methods for Source Classification:** Developed fast, high-dimensional phase-space trajectory pipelines to classify compact-object formation scenarios directly from gravitational-wave catalogs.
- **Tests of General Relativity:** Performed parametric and non-parametric tests of gravity in both weak- and strong-field regimes using current and next-generation gravitational-wave detectors.
- **Gravitational-Wave Bursts and Exotic Sources:** Studied hyperbolic encounters and unbound compact-object interactions as potential gravitational-wave burst sources and probes of dark matter and exotic compact objects.
- **Cross-Correlation with Large-Scale Structure:** Explored cross-correlation techniques between gravitational-wave events and galaxy catalogs to improve cosmological parameter inference.
- **Dark Matter with Gravitational Waves:** Investigated signatures of dark matter distributions and exotic compact objects through their imprints on gravitational-wave observations.
- **Dark Energy Consistency Tests with Cosmological Probes:** Developed a dataset-consistency framework using distance duality to assess dark-energy evolution in combined supernova (SN) and BAO observations.

## Presidency University, Kolkata, India

*Master's Thesis*

**November 2021 – July 2022**

Advisor: Dr. Suchetana Chatterjee

- Studied the mass function and growth history of supermassive black holes and their astrophysical implications.

## Skills

**Programming & Tools:** Python, C++, Fortran, Mathematica, MATLAB, HTML, Git, L<sup>A</sup>T<sub>E</sub>X

**Operating Systems:** macOS, Linux, Windows

**Cluster Computing:** High-Performance Computing (HPC)

## Collaborations

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Active Member of LIGO-Virgo-KAGRA Scientific Collaboration

## Lead Author Publications

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- Afroz, S., Navdha, & Mukherjee, S. (2025). *Are all Binary Black Holes Detected by LVK Following the Universal Time-Delay Distributions? Probably Not.* [arXiv:2510.06352](https://arxiv.org/abs/2510.06352) [astro-ph.HE].
- Afroz, S. & Mukherjee, S. (2025). *The Non Parametric Reconstruction of Binary Black Hole Mass Evolution from GWTC-4.0 Gravitational Wave Catalog.* [arXiv:2509.25356](https://arxiv.org/abs/2509.25356) [astro-ph.HE].
- Afroz, S. & Mukherjee, S. (2025). *Binary Black Hole Phase Space Discovers the Signature of Pair Instability Supernovae Mass Gap.* [arXiv:2509.09123](https://arxiv.org/abs/2509.09123) [astro-ph.HE].
- Afroz, S. & Mukherjee, S. (2025). *Gravitational Wave Burst from Bremsstrahlung in Milky Way Can Discover Sub-Solar Dark Matter in Near Future.* [arXiv:2507.22126](https://arxiv.org/abs/2507.22126) [astro-ph.CO].
- Afroz, S., Mukherjee, S., & Tasinato, G. (2025). *Illuminating Dark Energy with Bright Standard Sirens from Future Detectors.* [arXiv:2507.06340](https://arxiv.org/abs/2507.06340) [astro-ph.CO].
- Afroz, S. & Mukherjee, S. (2025). *The Phase Space of Low-Mass Binary Compact Objects from LVK Catalog: Hints on the Chances of Different Formation Scenarios.* [arXiv:2505.22739](https://arxiv.org/abs/2505.22739) [astro-ph.HE].
- Afroz, S. & Mukherjee, S. (2025). *Hint towards Inconsistency between BAO and Supernovae Dataset: The Evidence of Redshift Evolving Dark Energy from DESI DR2 is Absent.* [arXiv:2504.16868](https://arxiv.org/abs/2504.16868) [astro-ph.CO].
- Afroz, S. & Mukherjee, S. (2024). *Multi-messenger Cosmology: A Route to Accurate Inference of Dark Energy beyond CPL Parametrization from XG Detectors.* JCAP 03 (2025) 070, [arXiv:2412.12285](https://arxiv.org/abs/2412.12285) [astro-ph.CO].
- Afroz, S. & Mukherjee, S. (2024). *Phase Space of Binary Black Holes from Gravitational Wave Observations to Unveil its Formation History.* Phys. Rev. D 112 (2025) 2, 023531, [arXiv:2411.07304](https://arxiv.org/abs/2411.07304) [astro-ph.HE].
- Afroz, S. & Mukherjee, S. (2024). *Prospect of Precision Cosmology and Testing General Relativity using Binary Black Holes-Galaxies Cross-correlation.* Mon. Not. R. Astron. Soc. 534 (2024) 2, 1283–1298, [arXiv:2407.09262](https://arxiv.org/abs/2407.09262) [astro-ph.CO].
- Afroz, S. & Mukherjee, S. (2024). *A Model-independent Precision Test of General Relativity using LISA Bright Standard Sirens.* JCAP 10 (2024) 100, [arXiv:2406.08791](https://arxiv.org/abs/2406.08791) [astro-ph.CO].
- Afroz, S. & Mukherjee, S. (2023). *A Model-independent Precision Test of General Relativity using Bright Standard Sirens from Ongoing and Upcoming Detectors.* Mon. Not. R. Astron. Soc. 530 (2024) 4, 3812–3826, [arXiv:2312.16292](https://arxiv.org/abs/2312.16292) [astro-ph.CO].
- Full list available at: [inspirehep.net/authors/2741174](https://inspirehep.net/authors/2741174)

## Presentations / Talks

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- **A Model-Independent Precision Test of General Relativity with Gravitational Waves: A Multi-Messenger Approach**, presented at the *LVK Cosmology Working Group*, December 15, 2023.
- **Prospect of Precision Cosmology and Fundamental Physics test using Binary Black Holes- Galaxies Cross-correlation**, presented at the *LVK Cosmology Working Group*, June 28, 2024.
- **Invited Talk: A New Model-Independent Test of GR with Gravitational Waves**, presented at the *Testing Gravity with Multi-messenger Astronomy, IIT-Bombay*, July, 2024.
- **A New Model-Independent Test of GR with Gravitational Waves**, presented at the *Cosmology F2F, LVK Meeting Barcelona 2024*.
- **Phase Space of Binary Black Holes from GW Observations: A Probe to the Tale of its Formation History**, presented at the *LVK Rates & Population Working Group*, October 31, 2024.
- **Exploring New Physics and Testing General Relativity with Gravitational Waves**, presented at the *Ligo India Scientific Collaboration Meetings*, November 12, 2024.

- Prospects of Precision Cosmology with Gravitational Waves: Blinded Mock Data Challenge and Benchmarking, presented at the *Ligo India Scientific Collaboration Meetings*, November 19, 2024.
- **Invited Talk: Route to Accurate Inference of Dark Energy Equation of State using GWs**, presented at the *International Conference: Tensions and Anomalies on the Sky – Quest for New Physics at Cosmological Scales, Jamia Millia Islamia*, March, 2025.
- **The Phase Space of Low-Mass Binary Compact Objects from LIGO-Virgo-KAGRA Catalog**, presented at the *LVK Rates & Population Working Group*, May 15, 2025.
- Evidence of PISN mass scale of Black Hole Mass from GWTC-4 using Phase Space Technique, presented at the *LVK Cosmology Working Group*, August 28, 2025.
- Non-Parametric Reconstruction of Binary Black Hole Mass Evolution from Gravitational Wave Catalog GWTC-4, presented at the *LVK Rates & Population Working Group*, September 18, 2025.
- Delay Time Distributions of Binary Black Hole Mergers: A GridBased Inference from GWTC-4, presented at the *LVK Rates & Population Working Group*, September 25, 2025.
- **Invited Talk: Multi-Messenger Cosmology using bright and dark sirens**, presented at the *Cosmic Origins and the Search for New Physics*, January, IIT Madras 2026.

## Professional Service / Organizing Activities

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**Local Organizing Committee Member, GW-EM-Nu-2023: Role of India in Multi-Messenger Astrophysics and Cosmology** November 20–24, 2023

Tata Institute of Fundamental Research, Mumbai, India

- Served on the local organizing committee for a national multi-messenger astronomy conference, facilitating coordination of participants, logistics, and conference activities.

**Organizing Committee Member, Young Astronomers' Meet (YAM 2025)** March 18–21, 2025

Tata Institute of Fundamental Research, Mumbai, India

- Served on the organizing committee for YAM 2025, an initiative supported by the Astronomical Society of India, which provided a platform for emerging researchers in astronomy, astrophysics, and cosmology to present their work and network with peers.

**Local Organizing Committee Member, GW-EM-Nu-2025: Multi-Messenger Science With Indian Facilities – Now and in the Next Decade** December 1–3, 2025

Tata Institute of Fundamental Research, Mumbai, India

- Served on the local organizing committee for a national multi-messenger astronomy conference, facilitating coordination of participants, logistics, and conference activities.

**Organizer, Department of Astronomy and Astrophysics Journal Club** January 2024 – May 2025

Tata Institute of Fundamental Research, Mumbai, India

- Organized and coordinated a regular departmental journal club.

## Schools/Lectures/Courses/Workshops

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**International Centre for Theoretical Sciences (ICTS) – TIFR, Bengaluru, India**

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**July–04 August 2023**

*Summer School on Gravitational-Wave Astronomy*

- Intensive training in numerical relativity and computational techniques for compact binary simulations, including the 3 + 1 decomposition of Einstein's equations, ADM and BSSN formulations, gauge conditions, and constraint stability.
- Studied relativistic hydrodynamics in curved spacetime, high-resolution shock-capturing methods, and applications to neutron star mergers and core-collapse scenarios.
- Covered well-posedness of PDEs, hyperbolic systems, and numerical methods (spectral and finite-difference) used in computational relativity.

**42nd Annual Meeting of the Astronomical Society of India (ASI 2024)**

**January 31 –**

**February 4, 2024**

- Attended the annual meeting of the Astronomical Society of India and presented a *a poster* on tests of general relativity using gravitational-waves.

**International Centre for Theoretical Sciences (ICTS) – TIFR, Bengaluru, India 01–12 July 2024**

*Summer School on Gravitational-Wave Astronomy: Continuous Gravitational Waves*

- Advanced training on astrophysical and exotic sources of continuous gravitational waves in the context of LIGO–Virgo–KAGRA observations.
- Studied neutron star structure and evolution, GW emission mechanisms (mountains, r-modes), and continuous-wave search methodologies.
- Learned about superradiant instabilities and ultralight boson clouds around spinning black holes, and their GW signatures.

**International Conference: Testing Gravity with Multi-messenger Astronomy July 22–24, 2024**

*Indian Institute of Technology Bombay, Mumbai, India, India*

- Attended an international conference focused on Modified gravity.
- Delivered an *invited talk* on New Model-Independent Test of GR with Gravitational Waves.

**Eccentricity Workshop: Challenges in Unraveling Astrophysical Eccentric Compact Binaries March 1–4, 2025**

*Centre for Strings, Gravitation and Cosmology (CSGC), IIT Madras, Chennai, India*

- Attended a focused workshop on the dynamics, detection, and modeling of eccentric compact binaries in gravitational-wave astronomy.

**International Conference: Tensions and Anomalies on the Sky – Quest for New Physics at Cosmological Scales March 6–8, 2025**

*Centre for Theoretical Physics, Jamia Millia Islamia (JMI) in collaboration with IUCAA, India*

- Attended an international conference focused on cosmological tensions, dark matter, dark energy, and new physics beyond the standard model.
- Delivered an *invited talk* on dark energy reconstruction using gravitational-wave observations, highlighting constraints on cosmological parameters from GW standard sirens.

**Discussion Meeting: The Future of Gravitational-Wave Astronomy October 27–31, 2025**

*International Centre for Theoretical Sciences (ICTS) – TIFR, Bengaluru, India*

- Participated in a discussion meeting marking the 10th anniversary of the first gravitational-wave detection, focused on future directions in GW physics and astronomy.
- Presented *four posters and delivered a flash talk* on topics related to gravitational-wave astrophysics and cosmology.

**Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune, India 15–19 December 2025**

*GW Detector Characterization Workshop*

- Training in detector characterization for ground-based GW detectors, focusing on instrumental and environmental noise sources relevant for LIGO, Virgo, and LIGO–India.
- Hands-on experience with data-quality, glitch analysis, and signal-noise discrimination techniques.
- Exposure to detector commissioning challenges and noise mitigation strategies critical for improving GW search sensitivity.

**International Conference: Cosmic Origins and the Search for New Physics January 19–23, 2026**

*Indian Institute of Technology Madras, Chennai, India*

- Attended an international conference focused on early-universe physics, primordial gravitational waves, cosmological anomalies, and searches for new physics.
- Delivered an *invited talk* on the role of gravitational waves and galaxy surveys in probing cosmology.

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