SAMSUZZAMAN AFROZ

PhD Researcher in Gravitational-Wave Astrophysics and Cosmology
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Education

PhD in Gravitational-Wave Astrophysics **2022–2027 (expected)**
Tata Institute of Fundamental Research (TIFR), Mumbai, India

M.Sc. in Physics **2020–2022**
Presidency University, Kolkata, India

B.Sc. (Hons) in Physics **2017–2020**
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

Tata Institute of Fundamental Research (TIFR), Mumbai, India January 2023 – Present
PhD Research Student 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 **November 2021 – July 2022**
Master's Thesis 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, LaTeX
Operating Systems: macOS, Linux, Windows
Cluster Computing: High-Performance Computing (HPC)

Collaborations

Active Member of LIGO-Virgo-KAGRA Scientific Collaboration

Lead Author Publications

- **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 [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 [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 [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 [astro-ph.CO].
- **Afroz, S.**, Mukherjee, S., & Tasinato, G. (2025). *Illuminating Dark Energy with Bright Standard Sirens from Future Detectors.* arXiv: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 [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 [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 [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 [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 [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 [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 [astro-ph.CO].
- **Full list available at:** inspirehep.net/authors/2741174

Presentations / Talks

- **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 od 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

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.

Schools/Lectures/Courses/Workshops

International Centre for Theoretical Sciences (ICTS) – TIFR, Bengaluru, India **24 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 realativity 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 cosmology using gravitational waves, highlighting the role of GW observations in probing primordial physics and fundamental cosmology.

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