Milind Sarkar

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Education

Indian Institute of Science Education and Research Mohali (IISERM) *[2022 - 2027]*
Bachelor and Master of Science (BS-MS) | *Department of Physics* |
Pursuing a major in **Physics**, along with a minor degree in **Data Science**.

Julien Day School, Kalyani *[2017 - 2021]*
High School Diploma | *Council for Indian School Certificate Examinations(CISCE)* |
Completed high school with a concentration in **Science** | ICSE - **98** | ISC - **96** |

Research Interests

Computational Astrophysics, Galactic Dynamics and Evolution, Galaxy Morphology, Gamma Ray Bursts, Statistical Astronomy, Machine Learning & Data Science

Publications

- M.G. Dainotti, S. Bhardwaj *et al.* incl. M. Sarkar ; **GRB Redshift Classifier to Follow-up High-Redshift GRBs Using Supervised Machine Learning** [arXiv:2408.08763] ; *Currently under review at Astrophysical Journal Supplements*
- A. Narendra, M.G. Dainotti, M. Sarkar *et al.*; **GRB Redshift Estimation using Machine Learning and the Associated Web-App** [arXiv:2410.13985] ; *Currently under review at Astronomy and Astrophysics*
- M. Sarkar, M.G. Dainotti, A. Narendra *et al.*; **Redshift Classification of High-Redshift Optical GRBs Using Supervised Machine Learning** ; *Manuscript in Progress for submission to Journal of High Energy Physics(JHEP)*
- M. Sarkar, U. Banik *et al.*; **Dark Matter Density & Annhilation at Galactic Center** ; *Manuscript in Progress for submission in ApJ*
- M. Sarkar, A. Ghosh *et al.*; **Estimating Morphological Parameters and Their Uncertainties for Galaxies in multiple bands of the Hyper Suprime-Cam Wide Survey Using Machine Learning** *Manuscript in Progress for submission in ApJ*

Conferences

- M. Sarkar, A. Ghosh; **Multi-Wavelength Structural Parameter Analysis for 8 Million Galaxies in the Hyper Suprime-Cam Wide Survey** Submitted to ASI 2025
- M. Sarkar, A. Ghosh; **Multi-Wavelength Structural Parameter Analysis for 8 Million Galaxies in the Hyper Suprime-Cam Wide Survey** Submitted to APS Global Physics Summit 2025

Research Experience

Undergraduate Research Assistant *[May 2024 - Present]*
DiRAC Institute, University of Washington, Seattle | *Dr. Aritra Ghosh* |

- Utilized the Galaxy Morphology Posterior Estimation Network **(GaMPEN)** to estimate morphological parameters and uncertainties for approximately 8 million galaxies in the Hyper Suprime-Cam Wide survey
- Conducted an extensive literature survey of techniques in **Galaxy Morphology and Machine Learning** used for Large Astronomical Surveys.
- Employed **GaMPEN**, a machine-learning framework, to estimate **Bayesian posteriors** for a galaxy's bulge-to-total light ratio (LB/LT), effective radius (Re), and flux (F).
- Implemented a **two-step training process**: initial training on simulated galaxies followed by transfer learning with real data, utilizing less than 1% of the total dataset.
- Demonstrated that GaMPEN's predicted **posterior distributions** are well calibrated (within $\approx$5% deviation) and accurate compared to traditional light profile fitting methods, which underestimate uncertainties by up to $\approx$60%.
- Compared derived morphological parameters with **one external catalog** for an overlapping subsample, finding agreement within GaMPEN's predicted uncertainties.
- Established an **empirical relationship** between the Sérsic index and LB/LT, facilitating conversion between these parameters.

Undergraduate Research Assistant *[Jan 2024 - Present]*

Institute for Advanced Study & Princeton University | Dr. Uddipan Banik |

- Conductied an extensive literature survey of techniques in **n-body simulations and Galactic Dynamics**
- Made a Python Script to efficiently create **Initial Conditions(ICs)**, mainly positions and velocities in 3D, of galaxies for evolution simulations.
- Modified the IC Generator Script to evaluate theoretical as well as recovered densities, masses and energies of density profiles, namely, **Plummer, Hernquist and Dehnen**. These recovered densities account for the simulated galaxy profile.
- Ran Gadget2 halo simulations for **10 Gyr** (comparable to the age of our universe) for 10^5 to 10^6 particles with equal masses and the total mass of the galaxy ranging from 10^9 to 10^{11} times the mass of our sun and analyzed which distributions are stable enough.
- Performed complex calculations and analyzed from simulations the **optimal softening** factor e for our simulations.
- Planted a **supermassive particle** at the centre of the galaxy to mimic a black hole, ran the halo simulations for 10Gyr, and analyzed the response of the galaxy with a stable mass black hole at the centre
- Made a wrapper code for Gadget2 which can utilise Gadget2 to perform halo simulations with a **increasing mass black hole** at the centre of the galaxy and analyzed the response in the form of a **density spike** around the black hole
- Currently studying on search of a neutrino signal from the spike which could either set upper bounds on the **density slope of the inner halo** or clarify the nature of dark matter.

Undergraduate Research Assistant *[Dec 2023 - Present]*

National Astronomical Observatory of Japan | Prof. Maria Giovanna Dainotti |

1. **GRB Redshift Estimation using Machine Learning**
   - Expanded the sample of **long gamma-ray bursts (LGRBs)** with measured redshifts by **20%**, using a machine learning model trained on **30 additional GRBs.**
   - Developed the **first user-friendly web app** for inferring redshifts of LGRBs with plateau emission, allowing the community to estimate redshifts by inputting GRB parameters.
   - Successfully estimated redshifts for 276 LGRBs, **increasing the sample by 110%,** with Monte Carlo simulations confirming the model's future applicability for cosmological studies.
2. **Redshift Classification of X-Ray GRBs using Machine Learning**
   - Improved the **classification of high-redshift (z) gamma-ray bursts (GRBs)** by employing an ensemble machine learning (ML) method on 251 GRBs observed by the Neil Gehrels Swift Observatory, incorporating both plateau and prompt emission phases.
   - Achieved a sensitivity increase of **9% and 11% over Random Forest** alone, with 87% and 89% accuracy for redshift thresholds $z_t = 3.0$ and $z_t = 3.5$, respectively, using balanced sampling.
   - The **enhanced classification method** paves the way for more efficient follow-up observations of high-z GRBs, crucial for probing the early Universe.
3. **Redshift Classification of Optical GRBs using Machine Learning**
   - Applied ensemble machine learning to classify **gamma-ray bursts (GRBs)** into **high-** and **low-redshift** categories using **optical observations** from the Neil Gehrels Swift Observatory.
   - Incorporated both **prompt emission** and **plateau phase** data to improve classification accuracy, focusing on different **redshift thresholds** ($z_t = 2.0, 2.5, 3.0, 3.5$).
   - Achieved improved classification outcomes, with optimal performance at $z_t = 3.5$, enabling better **follow-up observations** of **high-redshift GRBs**.

Summer Research Student *[June 2023 - Aug 2023]*

Department of Physics, IISER Mohali | Prof. Jasjeet Singh Bagla |

- Examined a seminal paper in the field, breaking down its principles and transitioning to a **computational framework** for replication.
- Analyzed data obtained from the **GAIA DR-3** to determine gravitational wave properties utilizing statistical techniques to establish optimal fit lines for the data, enhancing our ability to draw meaningful conclusions.
- Estimated the **gravitational wave strain** in hypothetical binary black hole systems. involving complex calculations to quantify the impact of such systems on the spacetime fabric.
- Created **strain-frequency distributions** for stars near the Milky Way's galactic center. Applied statistical techniques to assess **data completeness** and created models to understand the collective contribution of binary systems to gravitational wave strain signals in galaxies.

Awards And Accolades

- Acheived a Rank **2227** in the JEE-Mains Examination, out of over **1 million** candidates *[2022]*
- Awarded the **Merit cum Means Scholarship** for at IISER Mohali. *[2024]*
- Awarded the **Chief Minister's Academic Excellence Award** for exemplery performance in ICSE.*[2019]*
- Awarded the **Dr B.R. Ambedkar Medha Puraskar** for exemplery academic performance in ICSE.*[2019]*

Reading Projects

Galactic Dynamics & N-body codes *[Jan 2024 - Aug 2024]*

Institute for Advanced Study & Princeton University | Dr. Uddipan Banik

- Explored the dynamics of elliptical galaxies and phase-space density in spherical systems, focusing on Jeans equations and potential-density pairs.
- Conducted an in-depth study of N-body simulations and numerical orbit integration, emphasizing Hamiltonian systems and symplectic integrators.
- Investigated the collisionless Boltzmann equation, Jeans theorems, and distribution functions for spherical systems, including applications of the virial theorem and integrals of motion.
- Examined particle-based and orbit-based models, Jeans and virial equations, equilibrium models, and response theory in homogeneous systems, covering the energy principle and dynamical friction.

Fundamental Astronomy *[Feb 2023 - Aug 2023]*

Department of Physical Sciences | IISER Mohali | Prof. Pankaj Kushwaha

- Investigated the implications of the Cosmological Principle, examining the concepts of homogeneity, isotropy, and the Copernican Principle in understanding the universe's large-scale structure.
- Explored Friedmann models and the role of the cosmological constant in describing the universe's expansion, including the critical density and the effects of dark matter and dark energy.
- Analyzed the Big Bang Theory and the subsequent formation of cosmic structures, studying the history and possible future scenarios of the universe's expansion.

Technical Skills

Software	Gadget-2, Nemo-GyrFalcon, Galfit
Tools and Web Dev	Git, GitHub, LaTeX, HTML, CSS
Languages	Python, C, C++, Java
Libraries	Pynbody, Galsim, Astropy, sklearn, fitsio, PyTorch, Tensorflow, SciPy, NumPy, Pandas, Matplotlib

Key Courses Undertaken

Physics	Classical Mechanics,Quantum Mechanics, Electrodynamics, Waves & Optics, Mathematical Methods †, & Statistical Mechanics
Astronomy	Astronomy & Astrophysics
Mathematics and CS	Linear Algebra & Group Theory, Probability & Statistics, Real Analysis, Differential Geometry, & Introduction to Programming
Online	Data-Driven Astronomy, Machine Learning, Neural Networks & Deep Learning

†*to be completed by Dec 2024*

Extra-Curricular Activities

- **Technical**
  - Served as the outreach volunteer of the physics club at IISER Mohali *Phi@I* and was responsible for increasing the presence of *Phi@I* on academic Twitter in the academic year - 22-23 .
- **Sports**
  - Won the Gold Medal at the Inter Hostel Table Tennis Tournament in 2023

Volunteer Experiences

Educational Outreach *[Aug 2023 - Jan 2024]*

National Service Scheme | IISER Mohali

Mentored underprivileged students in English and Mathematics. This included solving students' doubts and addressing other concerns.

References

Dr. Aritra Ghosh
Department of Astronomy & DiRAC Institute
University of Washington, Seattle
Email: aritrag@uw.edu

Dr. Uddipan Banik
Department of Astrophysical Sciences
Princeton University, New Jersey
Email: uddipan.banik@princeton.edu

Prof. Jasjeet Singh Bagla
Department of Physical Sciences
IISER Mohali, India
Email: jasjeet@iisermohai.ac.in

Prof. Maria Giovanna Dainotti
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