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, Statistical Astronomy, Machine Learning & Data Science

Publications

- M.G. Dainotti, A. Narendra, A. Pollo, **M. Sarkar** *et al.* | **Enhancing Redshift Estimates of Long Gamma-Ray Bursts Using Machine Learning** | *Manuscript in progress for submission to Astrophysical Journal Letters* |
- **M. Sarkar**, U. Banik | **Dark Matter Density & Annhilation at Galactic Center** | *Manuscript in Progress* |

Conferences

- **M. Sarkar**, A. Ghosh | **Estimating the Galaxy Morphological Parameters and Associated Uncertainties for Galaxies in the Hyper Suprime-Cam Wide Survey using Machine Learning** | Poster in Preparation for Abstract Submission at ASI 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 ≈5% deviation) and accurate compared to traditional light profile fitting methods, which underestimate uncertainties by up to ≈60%.
- Compared derived morphological parameters with **two external catalogs** 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 |

- Gamma-Ray Bursts (GRBs) have been detected up to redshift 9.4, showing potential as vital probes of early universe processes. However, only 11% of GRBs have known redshifts due to observational limitations.
- To address this, following Dainotti et al. (2024), we expanded our **training sample by adding 33 additional GRBs**, a 21% increase, estimating the redshifts of 154 long GRBs using an ensemble supervised machine learning model that incorporates X-ray afterglow and other parameters observed by the Neil Gehrels Swift Observatory.
- The estimated redshifts showed a strong correlation with observed redshifts, with a Pearson coefficient of 0.93 and a root mean square error of 0.46.
- Performed **Multivariate Imputation by Chained Equations (MICE)** on training data to filter the GRBs with missing variables.
- Performed **MCMC mock samples** resembling the observed data to check for how many years we can still use the current trained model before re-training the model again.
- The machine learning model inferred the redshifts of an additional — long GRBs and compared them to the **actual existing distribution**.
- Developed a freely accessible, **user-friendly web app** that automatically infers the redshift of long GRBs with plateau emission, providing real-time redshift estimates by entering observed parameters. This web app is the first of its kind and aids the community in obtaining rapid redshift estimates for new GRBs, enabling prompt follow-up studies and potential new discoveries.

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 Academic Excellence 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
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University of Washington, Seattle
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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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