Nandini Sahu

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Education

2017-present

Swinburne University of Technology, Melbourne, Australia
PhD candidate in Astrophysics

Thesis Title: "Morphology-Dependent Black Hole Mass Scaling Relations and The Pursuit of Long-Wavelength Gravitational Waves"

Primary Supervisor: Prof. Alister W. Graham
Co-Supervisors: A/Prof. Edward (Ned) Taylor, Dr. Benjamin L. Davis

2012-2017

Indian Institute of Technology (BHU) Varanasi, India
5-year Integrated Masters Degree in Engineering Physics

Master's Thesis Title: "Variation of Optical Depth of the Interstellar Medium Against the Supernovae Remnants"

Supervisor: A/Prof. Prasun Dutta

Bachelors Thesis Title: "Image Formation in Gravitational Lensing"

Supervisor: A/Prof. Prasun Dutta

Publications

First author

- **Sahu, N.** et al. 2020b, "Internal and Projected Density of Galactic Spheroid and Their Correlation With the Central Black Hole Mass." (To be submitted)
- **Sahu, N.** et al. 2020a, "Defining the (Black Hole)–Spheroid Connection with the Discovery of Morphology-dependent Substructure in the M_{BH}–n_{sph} and M_{BH}–$R_{e,sph}$ Diagrams: New Tests for Advanced Theories and Realistic Simulations". (Accepted in ApJ on 07/09/2020)
- **Sahu, N.** et al. 2019b, "Revealing Hidden Substructures in the M_{BH}–σ Diagram, and Refining the Bend in the L–σ Relation", ApJ, 887, 10.
- **Sahu, N.** et al. 2019a, "Black Hole Mass Scaling Relations for Early-type Galaxies. I. M_{BH}–$M_{*,sph}$ and M_{BH}–$M_{*,gal}$", ApJ, 876, 155.

Co- Author

- Ackley et al. including **Sahu, N.** 2020, "Neutron Star Extreme Matter Observatory: A kilohertz-band gravitational-wave detector in the global network". (Ackley et al. 2020, accepted)
- Sinha, T., **Sahu N.** et al. "The Characterization of Thick Gas Electron Multiplier (THGEM)", Published in the Proceedings of the 60th DAE –BRNS Symposium on Nuclear Physics 2015 (http://sympnp.org/proceedings/60/G36.pdf).

Conferences/Meetings/Talks

Sept 2020	The Royal Astronomical Society's Early Career Poster Exhibition. (Contributed poster)
Sept 2020	The 13th International LISA Symposium. (Contributed online talk)
July 2020	ASA Annual Scientific Meeting. (Contributed online talk)
June 2020	236th AAS meeting. (Contributed online talk , Session 307.2 - Evolution of Galaxies III)
Feb 2020	2nd Australia-ESO joint conference at Perth, WA. (Contributed talk)
Jan 2020	235th AAS meeting at Honolulu, Hawaii, USA. (Contributed talk)
July 2019	ASA Annual Scientific Meeting at Brisbane. (Contributed talk)
Dec 2018	OzGrav Annual Retreat and ECR Workshop at Perth. (Contributed poster)
June 2018	ASA Annual Scientific Meeting at Melbourne, VIC. (Contributed poster)

Expertise

- Expert in photometric image reduction and the two dimensional galaxy modeling.
- Expert in the multi-component decomposition of galaxy light.
- Confident with statistical regression and error propagation analysis.
- Well versed in 2D spectral data reduction, extraction, telluric correction, and flux calibration.
- Astronomical softwares: IRAF, ISOFIT, Profiler, DS9, SourceExtractor, CASA, and Topcat.
- Scripting: Python, Mathematica, Matlab, and C/C++.

Awards and Honours

- Recipient of the SUPRA scholarship to pursue PhD at Centre for Astrophysics and Supercomputing, Swinburne University of Technology, Melbourne, Australia.
- Won first prize in the OzSTAR image competition 2018 at Swinburne University of Technology.
- Awarded IIT (BHU) Varanasi gold medal in 2017 for exceptional academic performance during the five year Integrated Masters Degree (IMD) in Engineering Physics.
- Awarded Junior Research Fellowship by Indian Academy of Sciences (IAS) to work at SINP in summer 2015.
- Won the first prize on Institute day-2016 at department level for poster presentation of my work on THGEM.
- Got funded to attend IIST Astronomy and Astrophysics school (IAAS-2015) at the Indian Institute of Space Technologies, Trivandrum, Kerala.
- Recipient of Scholarship from GAIL (India) Limited in association with CSRL for first four years of Integrated Masters Degree (IMD) program.

Teaching Experience and Positions of Responsibility Held

2019	Tutor for 1st year physics course "Energy and Motion" at Swinburne University.	(sem 1, 24 students)
2016	TA for 2nd year physics course "Quantum Physics" at IIT-BHU Varanasi.	(sem 1, 40 students)
2016	TA for 1st year physics course "Classical, Quantum, and Relativistic Mechanics" at IIT-BHU.	(sem 1, 40 students)
2015	TA for 1st year course "Electrodynamics and Optics" at IIT-BHU Varanasi.	(sem 1, 40 students)
2014-15	Joint Secretary of Aero-modeling Club, IIT-BHU Varanasi.	
2014	TA for 1st year course Classical, Quantum, and Relativistic Mechanics at IIT-BHU Varanasi.	(sem 1, 40 students)

Research Experience

2017-present **PhD Candidate:** Morphology-Dependent Black Hole Mass Scaling Relations and The Pursuit of Long-Wavelength Gravitational Waves

ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav)
Centre for Astrophysics and Supercomputing (CAS)
Swinburne University of Technology, Melbourne, Australia

Thesis Aims: Investigate the correlation of central black hole mass with galaxy properties, search for the most fundamental relation using the largest to date sample of directly measured black hole masses, and further apply the latest scaling relations to improve the predictions for detection of the long-wavelength gravitational wave signals by ground-based and space-based detectors.

Project 1: Performed the image analysis (reduction, masking, 2D isophotal modeling, and multi-component decomposition) using near-infrared (NIR)-dominated large field of view and high-resolution images of galaxies with directly (dynamically) measured black hole masses (M_{BH}) taken from literature. Our image analysis provided us with stellar mass associated with each galaxy component including bulge ($M_{*,sph}$) and total galaxy stellar mass ($M_{*,gal}$) and the detailed morphology (presence of bar/stellar disk/ring/nuclear components/spiral arms) of our galaxies. We then investigated the correlation between black hole mass and both the bulge stellar mass and total galaxy stellar mass. This work revealed tight super-(log) linear (slope > 1) M_{BH}–$M_{*,gal}$ and M_{BH}–$M_{*,sph}$ relations which turn out to depend on galaxy morphology. (ApJ, 876, 155)

Project 2: Investigated the correlation between black hole mass and central stellar velocity dispersion (σ) of host galaxies, luminosity (L) versus σ relation, and the issue of claimed offset between galaxies with and without dynamically measured M_{BH} in the $M_{*,gal}$--σ diagram. This work discovered a break in the M_{BH}--σ diagram due to Sersic (gas abundant /wet merger driven) and core-Sersic (dry merger driven) galaxies and also recovered this bend in the L_{gal}--σ relation using our NIR-band data. Additionally, our (bent) $M_{*,gal}$--σ relation for galaxies with dynamically measured M_{BH} reduce the alleged offset. (ApJ, 887, 10)

Project 3: Expanding on project 1, in this work, we searched for correlations between M_{BH} and the basic spheroid properties (Sersic index, central concentration index, effective size) obtained during the image analysis. The results reinforced the morphological-dependence of black hole scaling relations with galaxy properties, with substructures consistent with M_{BH}–$M_{*,sph}$ relations. (Accepted in the ApJ)

Project 4: In this project, we numerically calculate (using vectorized *Mathematica* script) the de-projected (3D) internal (spatial) density profiles of galactic spheroids using their projected Sersic profile obtained in project 1. This work also reveals morphology-dependent correlations between black hole mass and spheroid internal density at various radii, along with the correlations of black hole mass with project densities, which are consistent with the substructure found the M_{BH}–$M_{*,sph}$ diagram. (To be submitted in the ApJ)

Project 5: This work is going to use our latest morphology-dependent black hole scaling relations and the latest morphology-aware galaxy mass function to improve the strain model for gravitation wave background specifically in the low frequency (micro-nano Hertz) regime. This model will then be used to improve the constraints (amplitude, event rate) for the detection of long-wavelength gravitational waves by pulsar timing arrays and laser interferometer space antenna (LISA).

2016-2017 **Master's thesis :** Variation of Optical Depth of the Interstellar Medium (ISM) Against the Supernovae Remnants

Indian Institute of Technology (BHU) Varanasi, India

- Thesis Aim: this project was aimed at measuring the optical depth of ISM against the CRAB nebula, using the HI 21cm absorption line. We used the data observed with the Giant Microwave Radio Telescope (GMRT), and analysed using the Common Astronomy Software Application package (CASA).
- Outcome: We found that the power-law index of the optical depth of cold neutral medium (CNM) towards CRAB nebula (l=184.56, b= -5.78) is consistent with that of shelled nebulae Cassiopeia A (l=111.74, b= -2.14) measured at the same scale ($\lesssim$ 1 pc). This implies a similarity in the scale dependence of opacity fluctuation and further similar density structure and temperature of the CNM along the two different galactic co-ordinates in the Milky Way.
- Experience gained: Learnt to reduce and analyse (radio) visibility data using CASA, and application of Chi-square analysis.

2016 **Research intern:** Near-Infrared (NIR) Spectroscopy of Young Stellar Objects

Indian Institute of Space science and Technology (IIST) Trivandrum

Supervisor: A/Prof. Sarita Vig

- Aim: My objective was to reduce and extract the NIR HK spectra of stellar members in proto-cluster IRAS 18511+0146, and recognize the features of evolving young stars.
- Outcome: I produced a manual describing the detailed procedure of NIR spectral reduction, spectrum extraction, telluric correction, and flux calibration using the NIR spectra of the stars in the IRAS 18511+0146 cluster, taken using Son OF Issac (SOFI) instrument onboard ESO 3.6 m New Technology Telescope (NTT). Seven out of 10 stellar objects show a rising spectral energy density, with three of them showing Brackett-γ (2.16 μm) emission line.
- Experience gained: This was my firsthand experience with real astronomical data. I learnt the whole rigorous spectral reduction and extraction process using IRAF and added to my knowledge of star formation and evolution.

2015-2016 **Bachelors thesis :** Image Formation in Gravitational Lensing

Indian Institute of Technology (BHU) Varanasi, India

- Thesis Aim: In this exploratory project my aim was to formulate the gravitational lensing caused by point mass and extended objects (galaxies/clusters), and form images of lensed sources using the corresponding gravitational potential models.
- Outcome: I simulated those formalisms using a Python script, where I applied the Rayshooting method to solve the lens equation to obtain the source position corresponding to the image position for various approximated lensing potential models (point mass, isothermal sphere, softened isothermal sphere, and non-circularly symmetric lens models), and also compared some images of lensed sources with the actual observations.
- Experience gained: This was my first ever research exposure to astrophysics which lead me to pursue it further. Here, I used Python for the first time.

2015 **Research intern:** The Characterization of Thick Gas Electron Multiplier
Saha Institute of Nuclear Physics (SINP) Kolkata
Supervisors: Prof. Sukalyan Chattopadhyay and Dr. Tinku Sinha

- Aim: Thick Gaseous Electron Multiplier (THGEM), is a modern high-efficiency ionization detector. My aim was to study the performance of indigenously designed and fabricated THGEM in the single-mode configuration, where it was used to detect the radiation emitted by Fe^{55} (Photo-peak 5.9 keV) in a gaseous medium of 9:1 mixture of Argon and Carbon-di-Oxide.
- Outcome: Gain of the detector was found to depend on input voltage and geometric properties of THGEM which can be tailored to obtain the optimum gain, suggesting that THGEM is an upcoming high-efficiency and high-resolution radiation detector. This work has been published in the proceedings of the 60th DAE-BRNS Symposium on Nuclear Physics.
- Experience gained: In addition to learning about conventional and advanced nuclear radiation detectors, on which I wrote a detailed report, this was my first experimental project where I learnt to calibrate/operate high energy equipments and data (signal) acquisition.

References

Reference 1
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Reference 2
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Reference 4
A/Prof. Edward (Ned) Taylor
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Science Coordinator | Galaxy and Mass Assembly (GAMA) Survey
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