Shubhit **Sardana**

Pulsar Timing Arrays · Gravitational waves · Radio Astronomy

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Education

Integrated Bachelor and Master of Science in Physics — **MP, India**

Indian Institute of Science Education and Research (IISER) - Bhopal — **Dec. 2021 - May 2026**

Current CPI (Cumulative Point Index): 8.26 (from a maximum of 10)

Publications

(Total Citations: 25, In-prep: 2, published: 2, Pre-print: 1, My ADS Library)

In order of relevance

1. Reading signatures of supermassive binary black holes in pulsar timing array observations — **2nd Author**

Published: **Nature Communications** — **Oct. 2025**

Goncharov, B., **Sardana, S.**, Sesana, A. et al. Reading signatures of supermassive binary black holes in pulsar timing array observations. Nat Commun 16, 9692 (2025). https://doi.org/10.1038/s41467-025-65450-3

2. Ensemble noise properties of the European Pulsar Timing Array. — **2nd Author**

Published: **Monthly Notices of the Royal Astronomical Society (MNRAS)** — **Feb. 2025**

Goncharov, B., & **Sardana, S.** (2025). Ensemble noise properties of the European Pulsar Timing Array. Monthly Notices of the Royal Astronomical Society, 537(4), 3470–3479. https://doi.org/10.1093/mnras/stw179

3. Statistical Physics from Quantum Envariance principle — **2nd Author**

Targeted Journal: **Physical Review A** — **Oct. 2025**

Ojha, A., **Sardana, S.**, & Ghosh, A. (2025). Statistical Physics from Quantum Envariance Principles. arXiv [Quant-Ph]. Retrieved from http://arxiv.org/abs/2510.25253

Research Experiences

Master's Thesis, Indian Institute of Science Education and Research (IISER) - Bhopal — **MP, India**

Thesis Supervisor: Dr. Mayuresh Surnis, IISER Bhopal, India

Co-Supervisor: M. A. Krishnakumar, NCRA, TIFR, India — **June 2025 - Present**

Topic: Using Interplanetary Scintillation for Dispersion Measure Corrections in Pulsar Timing Array Datasets

Working on using the interplanetary scintillation technique to understand heliospheric electron density variations and dispersion measure (DM) variations observed in the IPTA pulsar timing datasets. Developed a deep understanding of the mathematical modeling of heliospheric plasma. The methodology was validated using Murchison Widefield Array (MWA) archival data by performing calibration, cleaning, and imaging to estimate DM variations, yielding promising preliminary results. Currently extending this work using Ooty Radio Telescope (ORT) archival data to construct a heliospheric electron density map, compute corresponding DM variations, and develop a refined heliospheric model for Pulsar Timing Arrays (PTAs), further strengthening the overall analysis by improving consistency, reliability, and robustness across different observational datasets and processing stages.

Research Intern, Max Planck Institute for Gravitational Physics (AEI Hannover) **Remote**
Supervisor: Dr. Boris Goncharov **Aug. 2025 - Present**
Topic: The Targeted Siren Cosmology with Pulsar Timing Arrays

Working on precision cosmology using Pulsar Timing Arrays (PTAs) to constrain cosmological parameters (Hubble constant, matter density, dark energy density) through targeted continuous gravitational wave (CGW) searches using Galactic millisecond pulsars in PTAs. Utilizing realistically simulated CPTA and MPTA pulsar datasets to search for known supermassive black hole binaries (e.g., Gondor, Rohan, 3C 66B, 3C 454) exhibiting strong electromagnetic counterparts and strain amplitudes above the PTA sensitivity. I learned principles of CBC-inspiral and simulating the cgw effect from SMBHB using PTA Replicator, analyzing the injection to obtain posteriors on source parameters, and combining them with cosmological priors to achieve high-precision cosmological constraints.

Research Collaboration, Indian Pulsar Timing Array (InPTA) **InPTA Project**
Noise Analysis Group, InPTA **Feb. 2025 - June 2025**
Topic: Incorporating Solar Wind Gaussian Process in Pulsar Noise Modeling

Incorporated solar wind effects into pre-existing vanilla pulsar noise modeling for pulsars near the ecliptic plane in InPTA DR2 dataset. Developed and optimized pipelines, implemented Gaussian-process framework to model solar wind contributions to the dataset and validated the results across multiple pulsars. Regularly presented progress and collaborated on methodological improvements in the weekly group meetings.

Research Intern, Max Planck Institute for Gravitational Physics (AEI Hannover) **Hannover, Germany**
Supervisor: Dr. Boris Goncharov **May 2024 - Aug 2024**
Topic: Ensemble noise properties of the European Pulsar Timing Array

Implemented a novel method based on prior reweighting developed by Dr. Boris Goncharov to marginalise over uncertainties in the pulsar noise priors using EPTA DR2 dataset. Performed hierarchical Bayesian inference to infer the noise parameters of pulsars in the data. Accounting for the new prior distributions increases evidence for the Gravitational-wave background (GWB) as it makes inferred GWB parameters more consistent with theory while eliminating the systematic error from the measurement. This work resulted in two research papers: *"Ensemble Noise Properties of the European Pulsar Timing Array"* (MNRAS) and *"Reading signatures of supermassive binary black holes in pulsar timing array observations"* (Nature Communications).

Research Intern, Ludwig Maximilian University of Munich (LMU Munich) **Remote**
Supervisor: Dr. Karan Molaverdikhani **Dec. 2023 - Apr. 2024**
Topic: Analysis of Data from EVLA for Exoplanet Host Star Radio Emissions

Analyzed the TRAPPIST-1 system to search for potential star–planet interaction signatures in radio using EVLA archival data. Processed and calibrated a large amount of data using CASA and VLA pipelines, followed by detailed imaging and analysis. No definitive radio emission related to star-planet interactions was detected, likely due to sensitivity limits of current telescope. Future telescopes such as the ngVLA and SKA-Mid are expected to achieve the sensitivity required for such detections.

Research Intern, Indian Institute of Science Education and Research (IISER) - Bhopal **MP, India**
Supervisor: Dr. Mayuresh Surnis **Dec. 2023 - Dec. 2023**
Topic: Pulsar Search and Analysis Pipeline Development

Developed and optimized a PRESTO based pulsar search pipeline for GMRT data, integrated data cleaning, RFI mitigation using RFI Clean and incorporating efficient de-dispersion to correct frequency dependent delays from the interstellar medium and Earth's atmosphere. Improved the compute efficiency by implementing a sub-band shifting approach instead of shifting single frequencies, reducing the number of IO operations, maintaining precision. Analyzed the results and validated pulsar candidates under the supervision of Dr. Mayuresh Surnis, gaining extensive experience in pulsar signal processing and noise processes.

Research Intern, Indian Institute of Science Education and Research (IISER) - Bhopal — **MP, India**
Supervisor: Dr. Mayuresh Surnis — **May 2023 - July 2023**
Topic: Pulsar Search and Analysis of GMRT Data

Analyzed GMRT (Giant Metre-wave Radio Telescope) radio data to search for pulsars, gaining expertise in radio astronomy data processing and pulsar detection techniques. Converted raw telescope data into filterbank file format by incorporating metadata, and utilizing PRESTO (Pulsar Exploration and Search Toolkit) developed by Dr. Scott Ransom to search for pulsars. Applied RFI Clean for mitigating radio frequency interference and implemented algorithms for de-dispersing the frequency dependent signal delays introduced by the interstellar medium (ISM) and Earth's atmosphere. Performed potential pulsar candidate searching using Accelsearch script and filtering, developing a strong understanding of pulsar data and characteristics and detection pipelines.

Reading projects

Research Intern, Indian Institute of Science Education and Research (IISER) - Bhopal — **MP, India**
Supervisor: Dr. Mayuresh Surnis — **Sept. 2024 - Oct. 2024**
Fundamental concepts in Radio Interferometry

Studied the fundamentals of radio interferometry, including coherence, signal correlation, and antenna design through the Sixth NRAO Summer School (1998) lecture series under the supervision of Dr. Mayuresh Surnis. Touched on understanding the application of this foundation to explore astrophysical applications such as detecting faint and distant stars, analyzing molecular compositions of atmospheres of exoplanets around M and K type dwarf stars, and investigating its usage in star-planet interactions via radio emissions. Explored on synchrotron radiation from energetic charged particles in stellar and planetary magnetospheres and Quasars.

Conference/Teleconference Presentations

3. Indian Pulsar timing Array (InPTA)-wide Teleconference — **Teleconference**
Topic: (Research Paper) Exploring the time variability of the solar wind using LOFAR pulsar data. — **5th March 2025**

Presented in the InPTA-wide teleconference focusing on the importance of including the effects of solar wind in the pulsar timing. Mentioned the importance of integrating the effects due to solar wind plasma and electron density on the dispersion measure (dm) of signals from pulsars which lie very close to the solar disk. Showed the results from the first version of the script I built to analyze this process.

2. International Pulsar Timing Array (Gravitational-wave Analysis) Teleconference — **Teleconference**
Topic: (Two Research Papers) Ensemble noise properties of pulsars in EPTA and implications for GWB. — **17th Oct. 2024**

Gave a presentation in the GWA's bi-weekly Teleconference. GWA is one of the several working groups in the IPTA. The presentation focused on the key findings from the work done under the supervision of Dr. Boris Goncharov. This work has also been published in the form of two research papers.

1. European Pulsar Timing Array (EPTA)-wide Teleconference — **Teleconference**
Topic: (Research Paper) Ensemble noise properties of pulsars in EPTA. — **29th July 2024**

Presented in the EPTA-wide Telecon, a bi-weekly EPTA meeting. The presentation focused on the Ensemble noise properties of Pulsars, a research project that I did under the supervision of Dr. Boris Goncharov. This work has also been published as a research paper.

Skills

Programming Languages	Python (High Proficiency), C/C++ (Intermediate)
Statistical Techniques	Bayesian inference, Monte Carlo Markov Chain (MCMC), Hamiltonian Monte Carlo (HMC) & basic Frequentist inference
ML tools/frameworks	Normalizing flows, JAX framework, Discovery-Nanograv (GPU)
Astronomy Tools	Enterprise-Pulsar & enterprise-extensions, Astropy, PRESTO (PulsaR Exploration and Search TOolkit), tempo2, CASA and WSClean (Radio data processing & imaging) and many more tools.
Other Tools	Linux (Proficient), High Performance Computing (Proficient), Bash/Shell scripting (Intermediate), Mathematica, HTML5, CSS.

Related courses

Astronomy and Astrophysics, General Relativity, Cosmology, Special Relativity, Nuclear and Particle Physics, Statistical Mechanics, Wave and Optics, Electrodynamics, Non-Linear Dynamics and Chaos, Numerical Methods and Programming, Classical Mechanics, Quantum Mechanics, Advanced Quantum Mechanics, Atomic and Molecular Physics, Mathematical Methods - 1, Mathematical Methods - 2, Probability and Statistics, Signals and Systems.

Workshops and Certifications

- Attended a two-day Winter Conference on Condensed Matter Physics, Astrophysics & High Energy Physics Seventh Edition (2024) online, organized by The University of Tennessee, Knoxville, USA.
- Attended Sagan Summer Workshop 2023 online mode hosted by the NASA Exoplanet Science Institute, California Institute of Technology, Pasadena, CA, a 5-day workshop.
- Attended a 2-week workshop, Overview of Space Science (START Program) by the Indian Space Research Organisation (ISRO), held online.
- Studied the universe's evolution by taking a course by Dr. S. George Djorgovski at Caltech, where he taught The Evolving Universe on Coursera.