Rajat Saxena

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About

Master's student at LMU Munich with experience developing simulations in theoretical physics and astrophysics. My research interests lie in statistical mechanics and the physics of machine learning. I am also passionate about science outreach, philosophy and history.

Education

- **MSc in Physics** *October 2024 - Present*
  Ludwig Maximilian University (LMU) of Munich; ***Grade: 2.24*** *(1 Highest, 5 Fail)* Munich, Germany
  Advisor: Dr. Steffen Rulands, Professor, LMU

- **BSc Blended Physics** *June 2024*
  Savitribai Phule Pune University, ***CGPA: 9.32*** *(10 Highest, 4 Fail)* Pune, India
  Advisor: Dr Deepak Dhar, Distinguished Professor Emeritus, IISER - Pune

Research Experience

- **Universitäts-Sternwarte München** *March 2025 - September 2025*
  Research Intern
  Mentor: Dr Tilman Birnstiel, Professor
  - Developed N-body simulations to investigate the gravitational collapse of a dust cloud in the presence of a central star and a pre-formed gas disk.
  - Modelled particle trajectories coupled with gas dynamics during protostar formation, with integration of hydrodynamic snapshots (from Tārā) to interpolate density, velocity, and temperature fields beyond simplified disk models.
  - Summarised the group's research for Astrobites, translating complex results into accessible articles. Available: [🌐]

- **Indian Institute of Science Education and Research (IISER) – Pune** *August 2023 - May 2024*
  Bachelor Thesis
  Mentor: Dr Deepak Dhar, Distinguished Professor Emeritus
  - Studied foundational statistical mechanics and phase transitions through standard texts to build a strong theoretical base.
  - Developed a Python simulation of a 1D zero-temperature random field Ising model to investigate discrete magnetisation jumps in ferromagnetic materials with impurities and defects.
  - Analysed the impact of lattice size, random field standard deviation, and probability distributions on magnetisation curves, quantifying parameter-dependent behaviour.

- **Inter-University Centre for Astronomy and Astrophysics (IUCAA)** *June 2023 - July 2023*
  Summer Intern
  Mentor: Mr Ashish Mhaske, Scientific and Technical Officer
  - Led a student team to measure 21-cm neutral hydrogen power spectrum across different Galactic longitudes using a conical horn antenna.
  - Based on the Doppler-shifted HI line profiles, obtained the Milky Way Rotation Curve.
  - Designed and implemented a Python data-analysis pipeline to process source and calibration data.

- **National Centre for Radio Astrophysics (NCRA) - TIFR** *September 2022 – April 2023*
  Research Intern
  Mentor: Dr Yashwant Gupta, Distinguished Professor and Centre Director
  - Developed Python code for folding and binning time-series data to generate pulsar profiles for the Crab Pulsar using uGMRT data.
  - Implemented C routines to define on/off gates, enabling precise separation of pulsar on-pulse and off-pulse emission intervals.
  - Applied pulsar timing, dedispersion techniques, and correlator analysis, leveraging software tools such as TEMPO2 and GMRT Pulsar Tool (gptool).

AI/ML Projects

- **CNNs for Mass Estimation of X-Rays Clusters**
  Employed Convolutional Neural Networks (CNNs) to estimate Galaxy cluster masses from simulated X-ray images and redshift data of clusters. The redshift data was concatenated to the convoluted and flattened image data before being fed to the fully connected network.
- **Emergent Weight Morphologies in Deep Neural Networks**
  Investigated the emergent structural patterns in neural network weights that arise independently of the training data. Also examined how these structural patterns change with alterations in hyperparameters and training strategies.
- **Neural Networks for Quantum Many-Body Physics**
  Implemented a Restricted Boltzmann Machine (RBM) ansatz within a Monte Carlo framework to approximate the ground state of a Rydberg atom Hamiltonian. Utilised the expressive capacity of RBMs to represent many-body wavefunctions and employed stochastic gradient optimisation to minimise the variational energy.
- **Simulation-Based Inference for Bayesian Cosmological Data Analysis**
  Developed a simulation-based inference framework using autoencoder compression and normalising flows to recover cosmological parameters from Gaussian random fields. Benchmarked learned posteriors against analytic Fourier-space likelihoods, identifying effects of compression loss and autoencoder overfitting.

Outreach Experience

- **LIGO – India Education and Public Outreach (LI-EPO), IUCAA** *January 2023 – July 2024*
  Intern
  Mentor: Dr Debarati Chatterjee, Associate Professor and Chair LI-EPO
  - Developed outreach content and social media posts to communicate LIGO India's mission, maintaining interferometer demonstrations for public engagement.
  - Conducted awareness campaigns across Indian colleges, promoting the upcoming observatory.
  - Designed and led an introductory Python workshop for undergraduates, and assisted in organising Astronomy Teacher Training Workshops and local outreach at the Hingoli LIGO India site.
- **Science Popularisation Centre (SciPop), IUCAA**
  Volunteer
  - Operated telescopes and led stargazing sessions for school students and the general public, training new volunteers in telescope operation.

Mentorship Experience

- **Teaching Assistant at Quest Classes, Pune** (Aug–Oct 2024): Taught 12th-grade Physics (optics) and 11th-grade Mathematics (inequalities, combinatorics, binomial theorem).
- **Co-founder & Research Head, IDSS Space Society** (Oct 2021 – Jul 2023): Organised guest lectures, stargazing nights, school outreach programs, and space-themed MUNs; produced educational social media content. Recognised as a "Registered Space Tutor of ISRO" by CBPO, ISRO.

Selected Conferences

Oral Presentations

- **30th Young Scientists' Conference on Astronomy and Space Physics**, National University of Kyiv *April 2024*
- **10th National Student Symposium on Physics**, Indian Association Physics Teachers (IAPT) *October 2023*

Poster Presentations

- **Symposium on Magnetism and Spintronics**, Indian Institute of Technology - Bombay *July 2024*
- **National Space Science Symposium**, Indian Space Research Organization (ISRO) *February 2024*

Relevant Workshops

- **German Italian Physics Exchange**, German Physical Society & Associazione Italiana Studenti di Fisica *Sept 2025*
- **Summer University for Plasma Physics and Fusion Research**, Max Planck Institute for Plasma Physics *Sept 2025*
- **Summer School in Theoretical (Astro)Physics**, St Xavier's College & IUCAA *June 2024*
- **Course on Nuclear Experiments**, HBCSE-TIFR *March 2024*
- **Workshop on Data Science in Astronomy**, IUCAA *December 2023*

Skills

- **Programming Languages:** Python, Mathematica, Latex
- **Libraries:** Numpy, Scipy, Astropy, REBOUND, Matplotlib, Pandas
- **ML Libraries:** Keras/TensorFlow, Sklearn
- **Telescope Handling:** Dobsonian & Newtonian telescopes (EQ/Altazimuth mounts)
- **Softwares:** LAMMPS, ORCA, Astrometrica
- **Languages:** English (IELTS: 7.5), Hindi (Native), Marathi (Professional)

Awards and Achievements

- **Exceptional Accomplishments in Physics and Science Communication** *March 2024*
  Interdisciplinary School of Science, Savitribai Phule Pune University
  - Conferred by the Hon. Vice Chancellor in recognition of outstanding academic performance and science communication initiatives.
  - Acknowledged as a significant departmental honor highlighting excellence in both research and outreach.
- **Telescope Building Grant (INR 60,000)** *2022–23*
  Savitribai Phule Pune University
  - Received university funding to design and construct a Newtonian telescope.

Professional Memberships

- **Student Member of *"German Physical Society"*** *2025 - Present*
- **Student Member of *"Indian Physics Association"*** *2024 - Present*

Publications

[1] Saxena, Rajat. (2024). Introduction to Statistical Mechanics and Simulation of Random Field Ising Model. 10.13140/RG.2.2.34379.81443. Available: [🌐]

[2] **Saxena, Rajat** & Padalkar, Gauri & Patil, Yash & Sherkar, Shreenath & Satam, Harsh & Shah, Manasvi & Rajopadhye, Chinmayee. (2024). Galaxy Rotation Curve Measurements using a Horn Antenna. Available: [🌐]