

Mehul Goyal

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EDUCATION

Indian Institute of Technology Bombay

B. Tech. in Engineering Physics; **CGPA: 9.65/10.00**

Pursuing **Honors** in Physics

Mumbai, India

2022 – 2026

PUBLICATIONS

- U. Pathak et al. (including **M. Goyal**), “*Emission Mechanism and Jet properties of an Extremely Bright Gamma-Ray Burst-GRB 230812B*”, manuscript under preparation
- V. Swain et al. (including **M. Goyal**), “*GRB 230204B: GIT discovery of a fast fading afterglow of an extremely energetic GRB*”, manuscript under preparation
- R. Kumar et al. (including **M. Goyal**), “*Lunar elemental ratios as derived from Chandrayaan-2*”, manuscript under preparation

RESEARCH EXPERIENCE

Study of relativistic jets in GRB afterglows

[Github](#)

Guide: Prof. Varun Bhalerao | STAR Lab IIT Bombay

Dec 2023 – Present

- Studied GRB afterglow emission mechanisms like **synchrotron emission**, **forward** and **reverse shock** models
- Applied advanced statistical methods like **bayesian inference** and **dynamic nested sampling (MCMC)** for parameter estimation, model comparison, fit evaluation, and data-driven inference in GRB afterglows
- Developed **code** to generate synthetic lightcurves simulating the effects of **reverse shocks** and **wind type media**
- Created code to account for galactic and host galaxy **extinction** effects in the analysis of GRB afterglow spectra
- Applied **closure relations** & performed joint fitting to infer temporal, spectral & achromatic properties of GRBs
- Conducted analysis of forward shock dynamics in afterglows of GRB230204B, GRB130427A & GRB221009A

Application of Machine Learning to Asteroseismology

[Github](#)

Guide: Prof. Shravan Hanasoge | Tata Institute of Fundamental Research

May 2024 – Present

- Surveyed literature on asteroseismology of **solar-like oscillators**, focusing on analysis of main sequence stars
- Utilized python module **Lightkurve** to study data from Kepler LEGACY sample and K2 KEYSTONE samples
- Reviewed and customized the **Spectra-Simulator-C** by OthmanB to generate synthetic spectra of stars
- Initiated research into the PHOENIX stellar atmospheres library and examined literature on its applications
- Implemented custom **transformer** and **CNN** architecture for **image classification** tasks; integrating **multi-head self-attention**, patch embeddings & positional encoding techniques to optimize accuracy & efficiency

Mapping Lunar Chemical Abundances using X-ray fluorescence

High-prep ISRO problem statement at the Inter-IIT Tech Meet

Oct 2024 – Present

- Studied X-ray Fluorescence (XRF) and elemental detection methods related to solar flares incident on Moon
- Utilized Chandrayaan-2 Large Area Soft X-ray Spectrometer (CLASS) data to develop and implement a novel algorithm to detect solar flares based on strengths of elemental XRF lines and quality of their gaussian fits
- Created the first high-resolution map of XRF line ratios using GeoTIFF files, identifying compositional groups
- Manuscript under preparation under the guidance of ISRO scientists to publish the novel approach developed

Design Engineer | Mars Rover Team | IIT Bombay

Part of 10+ member subsystem that deals with daily software operations of the rover

Apr 2023 – Feb 2024

- Conceptualized the **Autonomous Navigation Pipeline** for rover in International Rover Design Challenge 2023
- Developed a **client-server system** for real-time ArUco Tag detection using Robot Operating System (**ROS**)
- Developed a bot with **differential drive mechanism** and client-server architecture to navigate ArUco tags
- Built a **simulation** framework for the rover's camera mechanism in **Gazebo**, optimizing functionality testing

KEY PROJECTS

Hunt for QCD Axion dark matter using gravitational lensing

[Report](#)*Krittika Summer Projects 2024 | Krittika: The Astronomy Club of IIT Bombay*

May 2024 – Jul 2024

- Studied the mathematical formulation of **gravitational lensing** and simulated lensing by a point mass
- Studied cosmology of **QCD axions**, focusing on early universe production mechanisms, **symmetry properties** dictating its interactions with baryonic matter, and the subsequent evolution of **axion dark matter**
- Investigated **QCD axion miniclusters** and methods to constrain the fraction of dark matter in miniclusters

LIGO-Inspired Disturbance Measurement System

Course Project : Analog Electronics | Prof. Pradeep Sarin | IIT Bombay

Jul 2023 – Dec 2023

- Characterized LED actuators by analyzing the **current-brightness relationship** and optimized the **phototransistor system** for improved **photometric accuracy**, ensuring precise calibration
- Implemented a **proportional controller**, using trial-and-error tuning to optimize performance, achieving **minimal steady-state error** and ensured system stability against small disturbances without inducing oscillations
- **Tested and calibrated system stability** by injecting known disturbances and verifying its capability to return to a stable state, successfully measuring its response to external, unknown disturbances such as flickering torch

Exploring the Radio Sky

[Github](#) | [Report](#)*Krittika Summer Projects 2023 | Krittika: The Astronomy Club IIT Bombay*

May 2023 – Jul 2023

- Analyzed **FITS** images of celestial jets at radio, infrared and visible wavelengths using the **CIRADA** data
- Acquired an in-depth understanding of **design, structure, and operational** mechanisms of radio telescopes
- Gained practical experience in **image deconvolution** and analysis of cleaned images using **CASA**
- Modeled the radio wavelength light curve of GW170817 using **MCMC** method to fit **smooth broken power law**
- Investigated **fast radio bursts**, focusing on the calculation of the **dispersion measure** for pulsar signals

Analysis of Gravitational Wave Event GW150914

[Report](#)*Course Project: Gravitational Wave Astronomy | Guide : Prof. Archana Pai | IIT Bombay*

Oct 2024 – Nov 2024

- Conducted detailed strain data analysis and used scaling arguments, Newtonian orbital dynamics, and Einstein's quadrupole formula to characterize the binary black hole merger GW150914
- Explored deviations due to orbital eccentricity, mass ratios, and spin effects, validating conclusions through reductio ad absurdum arguments
- Determined key system parameters, including chirp mass, compactness, orbital separation, and luminosity distance

WORKSHOPS

Radio Astronomy Winter School

NCRA-TIFR | IUCAA

Dec 2023

- Acquired foundational understanding of **electronics** involved in radio astronomy observations by conducting hands-on experiments on **transmission lines, superheterodyne receiver** and **Johnson-Nyquist Noise**
- Calculated **beam width** and offset of 4m radio telescope through azimuth, elevation and drift scans of the Sun
- Conducted observations of **HI** emission from galactic centre using **horn antenna** and analyzed the acquired data
- Collaborated within a team of 4 students to present in-depth analysis and discussion on **telescope team pattern experiment**, highlighting **findings, interpretations** and **insights** gained from the results of the experiment

ZTF Summer School (AI in Astronomy)

Zwicky Transient Facility & University of Minnesota, USA

Jul 2024

- Attended lectures on **Mixed Integer Linear Programming**, Simulation Based Inference & Anomaly Detection
- Performed **object detection** using a **region based CNN** and applied **MILP** for optimal scheduling of telescopes
- Trained **VGG16** model as **binary classifier** to detect and analyze light echos and stars in images & feature maps
- Developed and **optimized** ML models for **binary black hole detection** by incorporating knowledge from gravitational wave astrophysics to enhance accuracy and performance

MENTORING AND ORGANISATIONAL EXPERIENCE

Mentor | Krittika Summer Projects 2024

Krittika: The Astronomy Club IIT Bombay

May 2024 – Jul 2024

- Led a **two-month** long project for a group of **5** undergraduate and graduate students from various universities
- **Provided resources** to assist development of theoretical and practical understanding of **radio astronomy**
- Organized **regular weekly meetings** to address theoretical doubts & computational difficulties in allotted tasks

Teaching Assistant | Department of Physics

Course: Introduction to Classical and Quantum Physics, Analog Electronics Lab

Jan 2024 – Apr 2024

- Assisted in the course instruction, facilitating student learning by conducting **weekly tutorial** and **review sessions** for a batch of **30+** students, aiding in solving problems and grading the answer sheets
- Provided **hands-on guidance** during **weekly lab sessions** through **practical demonstrations**, supported students in understanding core concepts, and graded weekly assignments and examinations

Convener | Krittika: The Astronomy Club IIT Bombay

Part of a 10+ member team to cater to a community of 10K+ students

Jun 2023 – Apr 2024

- Organized and hosted **Astromania**, the annual astronomy quiz of IIT Bombay, attracting a participation of over **150+** individuals and contributed to the event's success by framing and presenting **30+** questions for the quiz
- Developed **radiation physics** and **radio astronomy** modules for Learner's Space, serving **150+** participants
- Effectively managed the **social media** handles of the club driving a growth of **128 %** in reach across platforms
- Organized **telescope learning sessions**, increasing public engagement and general awareness in astronomy

SCHOLASTIC ACHIEVEMENTS

- Secured **Department Rank 5** amongst a batch of **61** students in Engineering Physics (B.Tech) (2024)
- Secured **99.13** (Rank: 1351) percentile among **0.15 million** + candidates in the **IIT-JEE Advanced** Examination, the national-level highly-competitive examination for admission to Indian Institutes of Technology (2022)
- Secured **99.88 percentile** (Rank : 1167) out of **1 million** + candidates in the **JEE Mains** Examination, the national-level highly-competitive examination for admission to Science and Engineering programs (2022)
- Selected as one of **24** students **nationwide** to attend the Radio Astronomy Winter School at NCRA-TIFR (2023)
- Selected among **60** students **worldwide** to attend the ZTF summer school on AI in Astronomy (2024)
- Represented IIT Bombay as part of the Mars Rover Team in the prestigious **International Rover Challenge 2023**

COURSEWORK

Physics: Gravitational Wave Physics & Astronomy, Advanced Astrophysics, Introduction to Condensed Matter Physics, Electromagnetic Theory I & II, General Relativity, Quantum Mechanics I & II, Classical Mechanics, Oscillations and Waves, Statistical Mechanics, Non-Linear Dynamics, Thermal Physics

Mathematics: Group Theory Methods, Calculus I & II, Linear Algebra, Differential Equations, Complex Analysis and Integral Transforms, Numerical Analysis, Mathematical Structures for Control

Miscellaneous: Analog Electronics, Digital Electronics and Microprocessors, Computer Programming and Utilization, AI & Data Science, Makerspace, Economics

TECHNICAL SKILLS

Languages: Python, Git, MATLAB, C/C++, \LaTeX , Arduino, Bash, ROS **Softwares:** AutoCAD, Gazebo, CASA

Libraries: PyTorch, tensorflow, SciPy, AstroPy, Pandas, emcee, Dynesty, Matplotlib, OpenML, Eigen, lightcurve

REFERENCES

Prof. Varun Bhalerao

Department of Physics

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Prof. Shravan Hanasoge

Department of Astronomy & Astrophysics

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