



Ravi Kumar

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Student member of the Astronomical Society of India
Student member of the LIGO Scientific Collaboration

Education

Indian Institute of Technology, Bombay

Dept. of Aerospace Engineering

Bachelor of Technology in Aerospace Engineering with Minor in Data Science and Artificial Intelligence

October '21 - Present

CPI: 8.23/10

Publications & Conferences

- J. Basu, **R. Kumar** et al., “Discovery and Detailed Study of the M31 Classical Nova AT 2023tkw: Evidence for Internal Shocks” Submitted to the Astrophysical Journal
- D. Chatterjee, E. Marx, W. Benoit, **R. Kumar** et al., “Rapid Likelihood Free Inference of Compact Binary Coalescences using Accelerated Hardware” Accepted in Machine Learning: Science and Technology
- Tomás Ahumada, Shreya Anand, ..., **Ravi Kumar** et al., “Searching for gravitational wave optical counterparts with the Zwicky Transient Facility: summary of O4a” Accepted in Publications of the Astronomical Society of the Pacific
- Avinash Singh, R.S. Teja, ..., **R. Kumar** et al., “Unravelling the asphericities in the explosion and multi-faceted circumstellar matter of SN 2023ixf” Accepted in the Astrophysical Journal
- V. Swain, **R. Kumar** et al., “Rapid follow-up of GW events with a robotic optical telescope” Poster presented at the 32nd General Assembly of the International Astronomical Union at Cape Town, 2024

Research Experience

Simulation Based Inference for Parameter Estimation with LIGO

May '24 - Present

Guide: Prof. Michael Coughlin, School of Physics and Astronomy, University of Minnesota

- Worked with **JAX** and **Torch** to implement the **Sine Gaussian** and **IMRPhenomP** waveforms for inference on GPUs
- Performed statistical analysis on **Qp transformed** simulated timeseries strain data to obtain best-fit Q and p values
- Applied **Likelihood Free Inference** (LFI) and **Normalizing Flows** for **Parameter Estimation** (PE) of **Burst** and **Compact Binary Coalescence** (CBC) events using synthetically generated Binary Black Hole waveforms
- Implemented a multimodal model, using temporal and frequency data, achieving a $\sim 20\%$ lower validation loss
- Working to extend the existing PE infrastructure, allowing for inference of **Binary Neutron Star** (BNS) events

Optimization of Pipelines for GROWTH India Telescope

May '23 - July '24

Guides: Profs Varun Bhalerao (IITB), G.C. Anupama (IIA, retired), Sudhanshu Barway (IIA)

Data Reduction

- Improved the **image subtraction** pipeline by making use of **contour masking** techniques for diffraction spikes
- Implemented **weighted stacking** of images using variance **weight-maps** to deliver improved **limiting magnitudes**

Technical Experience

- Developed an **API** to transmit client requests for automating camera exposures and temperature control to a server using **HTTP** via **Flask**, executed with a **Visual Basic Script** (VBS) backend and synced the images using **SCP**
- Performed **on-site** maintenance by migrating from **Py2** to **Py3** and upgraded the **Telescope Control Software**
- Developed **Slack** bots to complete the transition of the existing GCN alert system to the **Apache Kafka** protocol

Observational Experience

- Discovered a nova **AT2023tkw** in **Andromeda** and published the results as AstroNote 2023-255, and ATel 16311
- Working with the international **GROWTH** collaboration on **EMGW** followups of LVK events – GCN 36080, 36246
- Performed optical follow-ups of **15+** GRBs and published the results as **NASA GCN Circulars** – GCN 37312, 37125, 37086, 35354, 35089, 35055, 35041, 35027, 34984, 34839, 34833, 34780, 34576, 34514, 34500, 34460, 34420
- Carried out observations and ephemeris calculations for multiple **possible comet** and Near Earth Objects (NEOs) and published the results on the **Minor Planet Center** as MPEC 2023-S264, 2023-R197, 2023-R115, 2023-O51

Semi-Transparent Coded Aperture Masks with DAKSHA

August '24 - Present

Guides: Profs Varun Bhalerao (IITB), A.R. Rao (TIFR, retired)

- Performed statistical analysis of GRB localisations by previous space missions **Fermi** and **Swift** to establish a baseline
- Obtained analytical expressions of uncertainty for Coded Aperture Mask (CAM) and Dispersed Detector localisations
- Simulated the Detector Plane Histogram, using **Cosmic X-ray Background** and the **Band spectrum** of GRBs
- Developed a **novel technique** for localisation by considering only low energy (<50 keV) photons to maximize contrast
- Achieved a $\sim 1^\circ$ localisation of 3×10^{-7} erg fluence sources

Statistical Analysis and Coverage Estimation with GIT

August '23 - November '23

Guide: Prof. Varun Bhalerao, Dept. of Physics, IITB

- Collated over **1500** Fermi GRB localisation maps spanning over **6 years** using web-scraping techniques in Python
- Performed simulations to optimize for total telescope time spent on follow ups based on probability coverage estimates
- Results include the follow-up of GRBs **231018A** (GCN 34839) and **231122A** covering $\sim 20\%$ of the probability map

Workshops

Zwicky Transient Facility Summer School

July '24 - August '24

5-day workshop on Artificial Intelligence in Astronomy - ZTF & University of Minnesota

- Attended lectures on Mixed Integer Linear Programming (MILP), Simulation Based Inference and Anomaly Detection
- Performed object detection using a **Region based CNN** and applied **MILP** for optimal scheduling of telescopes
- Implemented binary classifier with **VGG16** model to detect light echoes, stars in images and analyzed feature maps
- Trained models for transients, binary merger detection, and understood **DBSCAN** and **Gaussian Mixture Models**

Key Projects

Elemental Mapping of Lunar Surface with Chandrayaan-2

November '24 - Present

InterIIT Tech Meet 13.0: ISRO Problem Statement

- Studied the physics of X-ray Fluorescence (XRF) and its relation to solar flares incident on the 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 a **high-resolution** map of XRF line ratios using **GeoTIFF** files, identifying major **compositional groups**

Statistically Detecting Gamma Ray Bursts in CZTI | GitHub

May '23 - July '23

Krittika Summer Projects, IITB

- Studied physics of Gamma Ray Bursts (**GRBs**) and working of **AstroSat**'s Cadmium-Zinc-Telluride Imager (**CZTI**)
- Analyzed the unknown distribution of noise data present in the light curves by fitting various known distributions, namely the **Gaussian**, **Poisson**, **SkewNorm** and **Gamma** distributions and statistically determined the best fit
- Developed a robust algorithm to determine the **real/bogus** nature of a given signal by maximizing Signal-to-Noise Ratio (SNR) across timebins and eliminat outliers with $\text{SNR} > 3$ in different energy bands, obtaining **90%** accuracy

Time Series Analysis of Magnetic Cataclysmic Variables | Report

May '23 - July '23

Krittika Summer Projects, IITB

- Studied the physics governing **binary stars** and cataclysmic variables (**CVs**) with emphasis on **magnetic CVs**.
- Processed **Astrosat**'s **UVIT** data to generate light curves using the custom library **curvit**, and accurately obtained the **orbital period** of the Magnetic Cataclysmic Variable **BL Hyi** by analyzing its **Lomb-Scargle Periodogram**
- Performed **phase folding** and correction of **ephemeris** on the obtained light-curve, furthermore, calculated the magnitudes, fluxes, and luminosities associated with each phase to determine the **physical state** of the system.

Stellar Analysis of Clusters using Gaia | Report

May '23 - July '23

Krittika Summer Projects

- Employed parallax and proper motion quality cuts in a dataset of **1 billion+** stars to find distances of 5 open clusters
- Studied **phase space distribution** of spectral types in open clusters and obtained the Salpeter Initial Mass Function (**IMF**) by fitting **PARSEC isochrones** on its **HR diagrams** and found the age and metallicity for globular clusters

Representations of VQVAE Models on Parallel Datasets | GitHub

November '24

IE643 Course Project, Guide: Prof. P Balamurugan, IEOR, IITB

- Developed and analyzed **VQVAE models** to evaluate the impact of noise distributions in parallel datasets on latent space representations, by using **PCA**, **t-SNE**, **MDS** and **Isomap** as dimensionality reduction techniques
- Utilized statistical methods like **Kernel Density Estimation**, **Cosine Similarity**, **Mahalanobis Distance**, clustering to quantify and visualize the effect of **Gaussian**, **Poisson**, **Speckle** noise in the codebook vectors
- Built an interactive GUI with the dynamic evolution of codebook vectors during training, to compare noise effects

Analysis of Solar Flares and Prediction of Solar Activity | Github

November '22

Data Analysis (DS203) Course Project, Prof. Amit Sethi, Prof. Manjesh K. Hanawal

- Studied the underlying physics associated with **solar flares and activity** and collected datasets for further analysis
- Trained the **LSTM** and **Autoregressive** models on time series data from the **RHESSI** and **Konus-Wind** missions
- Achieved mean squared error of **0.014** and **0.024** on average using the Autoregression and LSTM models respectively

Recurrent Feature Reasoning for Medical Image Inpainting

April '24

CS736 Course Project, Guide: Prof. Suyash Awate, Computer Science and Engg. Dept., IITB

- Analyzed a novel **Recurrent Feature Reasoning** model for medical image inpainting on custom masked datasets
- Conducted experiments on various mask types and dataset variability, demonstrating **out-of-sample** generalizability
- Evaluated performance using **SSIM**, **PSNR** and **RMSE** metrics on Chest X-ray and SARS-COV-2 CT-Scan datasets

Weather Classification via Computer Vision | Github

April '24

Self Project

- Implemented a **ConvNet** model for transfer learning with **VGG16** backbone pre-trained on the **ImageNet** dataset
- Achieved an unprecedented validation accuracy of **85.61%**, seeing an improvement of **5.34%** over the original model.
- **Fine-tuned** the model with a head consisting of **flatten**, **dense** and **dropout** layers to improve accuracy by **4.38%**

Animal Classification using CNNs | Github

April '23

DS303 Course Project, Guide: Prof. Biplab Banerjee, CSRE, IITB

- Implemented a **Deep Learning** based research paper to classify animal species, achieving a training accuracy of **98%**
- Deployed **7 layers** with multiple filters, **dropout regularization**, **Adam optimizer** and **ReLU** activation function

Positions of Responsibility

Team Krittika - Volunteer

December '22 - April '23

The Astronomy Club of IIT Bombay

- Increased astronomy awareness in the institute by conducting a stargazing session by employing Electronically Assisted Astronomy (**EAA**) to display live footage of **comet C/2022 E3 (ZTF)** for an audience of **250+** students.
- Assisted in club outreach by regularly capturing and posting images of deep sky objects such as the **Orion Nebula**, **Leo Triplet**, and **Omega Centauri** along with a **transit** of the **International Space Station** across the Sun.

Professional Experience

Digantara | Technology Consulting Intern

May '24 - Present

Working with a team of engineers on developing advanced telescope automation systems

- Integrating **GNSS** modules to establish **microsecond-level** accurate automated exposures for a **CCD camera**
- Spearheading knowledge transfer to company engineers on topics of astronomy, telescope working and automation
- Integrating **ASCOM Alpaca** and **PlaneWave Interface (PWI4)** APIs using Python, setting up a system of multiple telescopes to enable automated scheduling, slewing and tracking for wide-field nightly survey of **non-sidereal** targets

Scholastic Achievements

- **99.27 percentile** in Joint Entrance Examination, Mains among over **0.9 million** candidates February '21
- **Top 1.15%** in Joint Entrance Examination, Advanced among over **0.14 million** candidates October '21

Courses Undertaken

| | |
|---------------------|---|
| Aerospace | Spaceflight Mechanics, Compressible and Incompressible Fluid Mechanics, Aircraft Propulsion |
| Mathematics | Numerical Analysis, Partial Differential Equations, Multi-variable Calculus, Linear Algebra |
| Data Science | Machine Learning, Programming for Data Science, Data Analysis and Interpretation |
| Other | Quantum Physics and Application, Basics of Electricity and Magnetism, Introduction to Electrical and Electronics Circuits, Computer Programming and Utilization |

Technical Skills

| | |
|------------------|---|
| Languages | Python, C++, SQL, HTML5, CSS, L ^A T _E X |
| Softwares | CCDLAB, SWarp, SExtractor, DS9, Siril |
| Libraries | AstroPy, NumPy, HealPy, SciPy, Pandas, Matplotlib, OpenCV, curvit |

Extra-Curricular Activities

- Contributed photographs displayed in **Kaladarshan**, the annual art exhibition of IITB March '22, '23 and '24
- Secured **second position** in the Photo Story competition at the **Inter-IIT Cultural Meet**, 6.0 December '23
- Devoted **80+ hours** of social service work under **Green Campus** department, National Service Scheme, IIT Bombay to spread awareness in the community by writing and circulating articles. November '21 - June '22

References

Prof. Varun Bhalerao

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