

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 CPI: 8.23/10 Bachelor of Technology in Aerospace Engineering with Minor in Data Science and Artificial Intelligence

Publications & Conferences

- J. Basu, R. Kumar et al., "Discovery and Detailed Study of the M31 Classical Nova AT 2023tkw: Evidence for Internal Shocks" Accepted in the Astrophysical Journal
- D. Chatterjee, E. Marx, W. Benoit, R. Kumar et al., "Rapid Likelihood Free Inference of Compact Binary Coalescences using Accelerated Hardware" Published 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" Published 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" Published in the Astrophysical Journal
- R. Kumar et al., "Semi-transparent coded aperture masks with Daksha" manuscript under preparation
- **R.** Kumar et al., "Lunar elemental ratios as derived from Chandrayaan-2" manuscript under preparation
- 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

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

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 (**NEO**s) and published the results on the Minor Planet Center as MPEC 2023-S264, 2023-R197, 2023-R115, 2023-O51

May '24 - Present

May '23 - July '24

October '21 - Present

1

Semi-Transparent Coded Aperture Masks with DAKSHA

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

- Obtained analytical expressions of uncertainty for Coded Aperture Mask (CAM) and Dispersed Detector localizations
- Simulated the Detector Plane Histogram, using Cosmic X-ray Background and the Band spectrum of GRBs
- Developed a **novel technique** for localization by considering only low energy (<50 keV) photons to maximize contrast
- Achieved a $\sim 1^{\circ}$ localization of 3×10^{-7} erg fluence sources, with plans to enhance the results using simulated background, denoising techniques and data from multiple detectors

Statistical Analysis and Coverage Estimation with GIT

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

- Collated over **1500** Fermi GRB localization 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 $231018A~({\rm GCN}~34839)$ and $231122A~{\rm covering}\sim}20\%$ of the probability map

Workshops_

Zwicky Transient Facility Summer School

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 $\mathbf{VGG16}$ model to detect light echoes, stars in images and analyzed feature maps
- Trained models for transients, binary merger detection, and understood ${\bf DBSCAN}$ and ${\bf Gaussian}$ ${\bf Mixture}$ ${\bf Models}$

Key Projects_

Mapping the Lunar Surface with Chandrayaan-2 | GitHub InterIIT Tech Meet 13.0: ISRO Problem Statement

- Lead a team of 15, securing the first position amongst 23 other IITs
- Studied X-ray Fluorescence (XRF) physics 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**

Statistically Detecting Gamma Ray Bursts in CZTI | GitHubMay '23 - July '23Krittika 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 eliminate outliers with SNR > 3 in different energy bands, obtaining 90% accuracy

Time Series Analysis of Magnetic Cataclysmic Variables | ReportMay '23 - July '23Krittika Summer Projects, IITBMay '23 - July '23

- Studied the physics governing **binary stars** and cataclysmic variables (**CV**s) 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

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

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

August '23 - November '23

July '24 - August '24

May '23 - July '23

November '24

November '24 - December '24

RAVI KUMAR · CURRICULUM VITAE

Analysis of Solar Flares and Prediction of Solar Activity | GitHub

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 Image Inpainting | GitHub

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

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

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

Professional Experience

Digantara | Technology Consulting Intern

- 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 Inferface (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

Positions of Responsibility_

Team Krittika - Volunteer

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.

Scholastic Achievements_

- 99.27 percentile in Joint Entrance Examination, Mains among over 0.9 million candidates
- Top 1.15% in Joint Entrance Examination, Advanced among over 0.14 million candidates

Courses Undertaken.

Data Science Deep Learning, Machine Learning, Medical Image Computing, Data Analysis and Interpretation Mathematics Numerical Analysis, Partial Differential Equations, Multi-Variable Calculus, Linear Algebra Quantum Physics and Application, Basics of Electricity and Magnetism, Electrical and Electronics Circuits, Other Modelling and Simulation, Navigation and Guidance, Computational Fluid Mechanics, Control Systems

Technical Skills

Languages Python, C++, SQL, HTML5, CSS, Java Script, LATEX, Visual Basic Script Softwares DOLPHOT, CCDLAB, SWarp, SExtractor, DS9, Siril Utilities Git, Apptainer, PyTorch, JAX, Poetry, AstroPy, Flask, OpenCV, NumPy, SciPy, TensorFlow, Matplotlib

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 November '21 - June '22 to spread awareness in the community by writing and circulating articles.

May '24 - August '24

December '22 - April '23

February '21 October '21

April '24

April '24

April '23

References

Prof. Varun Bhalerao

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