Aswin Suresh

Physics Undergraduate, Indian Institute of Technology Bombay
aswin.suresh@iitb.ac.in aswinsuresh24.github.io github.com/aswinsuresh24

Research Interests

Time Domain and Multimessenger Astronomy
Infrared Transients and Variables, Electromagnetic Counterparts to Gravitational Wave Sources, Gamma-Ray Bursts, Parameter Estimation of Binary Black Hole Mergers

Education

Indian Institute of Technology Bombay **2020 – Present**
Bachelor of Technology in Engineering Physics with Honors

Publications

a. *Refereed Publications:*

1. **A. Suresh**, V. Karambelkar, M. M. Kasliwal et al. "Automated Catalog of Long Period Variables with the Palomar Gattini-IR", arXiv:2402.08000
2. A. Y. Q. Ho, D. A. Perley, P. Chen, S. Schulze, V. Dhillon, H. Kumar, **A. Suresh** et al., "Minutes-duration Optical Flares with Supernova Luminosities", **Nature** 623, 927–931 (2023)

b. *In-prep:*

1. **A. Suresh**, V. Swain, H. Kumar, V. Bhalerao et al. "Real-time Transient Detection Pipeline for the GROWTH-India Telescope", manuscript under preparation
2. **A. Suresh** and A. Pai, "Constraining Eccentricity of Binary Black Hole Systems in Next Generation Detectors", manuscript under preparation

c. *Conferences and non-refereed Publications:*

1. **A. Suresh**, V. Karambelkar, and M. M. Kasliwal, "A Machine-Learning Generated Catalog of Long Period Variables with the Palomar Gattini-IR", Poster, Astronomical Society of India Meeting 2024
2. H. Kumar, I. Andreoni, **A. Suresh** and M. Coughlin, "ZTF Discovery of AT2023ghq, a fast fading blue transient", AstroNote 2023-99
3. General Coordinates Network (GCN) Notices: 17 published with 6 as first author, 11 as co-author

Research Experience

Automated Catalog of Long Period Variables from the Palomar Gattini-IR **June '23 – Present**
Guide: Prof. Mansi Kasliwal, Cahill Centre for Astronomy and Astrophysics, Caltech

- Implemented a **gradient-boosted decision tree classifier** using `LightGBM` to sift out Long Period Variables (**LPVs)** from Gattini lightcurves, achieving a true positive rate of 98% and a g-mean score of 0.97
- Assembled the training dataset for the classifier and **synthetically class-balanced** the dataset using adaptive synthetic upsampling of minority class and nearest neighbor downsampling of majority class using `imbalanced-learn`
- Designed a comprehensive set of 19 features for the classifier, folding in information about the periodicity, variability, and phasing extracted from **Gaussian process** interpolated lightcurves, in addition to querying infrared colors
- **Optimized** the feature extraction procedure to run in 0.1 seconds per lightcurve for **35 million** lightcurves
- Constructed an extensive infrared catalog of LPVs, with 150,000 LPVs from Gattini, comprehensively analyzed catalog features, validated it with the Gaia catalog of LPVs, and estimated the **period amplitude relation** for AGB stars
- Obtained spectra of several large amplitude variables with non-sinusoidal variability predicted by the classifier as "non-LPVs" with the **triple spectrograph** instrument on Palomar Observatory

Image Subtraction and Candidate Vetting for GROWTH India Telescope **Aug '22 – Aug '23**
Guide: Prof. Varun Bhalerao, Dept. of Physics, IIT Bombay

Data Reduction Pipelines

- Reformulated the **image subtraction pipeline** of GROWTH India Telescope (GIT) by querying Pan-STARRS reference images, implementing **pixel-to-pixel alignment** of science and reference images using refined astrometry on smaller-sized cutouts, masking bright sources, and matching the flux of science and reference images
- Implemented a **deep-learning real-bogus classifier**, including assembling the training dataset by scanning over 150,000 alerts, using `TensorFlow` and `Keras`, achieving **99.14%** training accuracy and **97.2%** testing accuracy
- Developed software to discard false subtraction residuals from difference images robustly, remove fringing interference effects in CCD detectors, and improved the **candidate vetting** pipeline of GIT in preparation for LIGO O4

Observing Experience

- Carried out Target of Opportunity (**ToO**) observations, data reduction, and analysis of the flaring Fast Blue Optical Transient (FBOT) **AT2022tsd** and candidate ZTF **optical afterglows of GRBs** and fast transients using GIT in addition to observations of supernovae and nightly targets
- Assisted in GIT discovery and analysis of the optical afterglow of the **ultra-luminous** long GRB 230204B

Constraining Eccentricity of Binary Black Hole Systems in Future Detectors — August '23 – Present

Guide: Prof. Archana Pai, Department of Physics, IIT Bombay

- Generated waveforms of eccentric binary black hole (BBH) systems using the **EccentricTD** waveform and extracted higher harmonic signatures from the Q-transform using the Power Spectral Density of **Einstein Telescope**
- Developed metrics to **evaluate the performance and validity** of the effective chirp mass model, which estimates the chirp mass and eccentricity of BBH signals in the lower frequency cutoff range of 10 Hz to 3 Hz
- Developed novel techniques to optimally extract bright pixels from the Q-transform and match model and track frequencies using an **energy-weighted frequency deviation** metric, significantly improving eccentricity estimates
- Placed **strong constraints** on the eccentricity of BBH systems in low and high eccentricity regimes using the ratio of the energy contained in higher harmonic tracks to the fundamental track, **breaking degeneracy** between chirp mass and eccentricity

Hunting for Kilonovae with WINTER — May '23 – July '23

Guide: Prof. Mansi Kasliwal, Cahill Centre for Astronomy and Astrophysics, Caltech

- Developed **optical-infrared color templates** for color evolution of type Ia, Ib, IIb, and Ic supernovae and compared the color evolution of kilonova **AT2017gfo** to follow up interesting transients based on color information
- Implemented deep learning models for real bogus classification of infrared transient alerts for the Wide-field Infrared Transient Explorer **(WINTER)**
- Assisted in commissioning operations of WINTER for two weeks at Palomar Observatory and assembled a comprehensive set of infrared variable stars and transients for the **first light** observations of WINTER

Automation GRB Searches with the CZTI Interface for Fast Transients — November '21 – August '22

Guide: Prof. Varun Bhalerao, Dept. of Physics, IIT Bombay

- Developed a pipeline to **inject artificial Gamma-Ray Bursts** in raw event data from the Cadmium Zinc Telluride Imager (CZTI) aboard AstroSat to quantify the efficiency of CZTI data processing pipelines using T90 and SNR calculations
- **Automated untriggered searches** for GRBs in CZTI data with functionalities to process bulk data as well as day-to-day data inflow using CZTI Interface for Fast Transients - an automated pipeline to identify bursts from lightcurves and time-energy plots
- Carried out triggered and untriggered searches for GRBs with **ten** GCN Notices published in 2022
- Created a 40-second **animation** of the **spatial distribution of Gamma-Ray Bursts** detected by AstroSat CZTI to commemorate its detection of 500 GRBs, highlighted extensively by press and media agencies

Automated Identification of Solar Flares — March '22 – November '22

Indian Space Research Organization (ISRO)

- Developed *SuryaDrishti*, a standalone web-based application using Python and Angular to **identify and categorize** X-ray bursts from **Solar X-ray Monitor** aboard Chandrayaan-2 based on peak energy flux
- Led the implementation of **statistical algorithms** to identify solar flares from raw data and used an Elementary Flare Profile **(EFP)** fit to extract properties of scientific interest such as Temperature and Emission Measure
- Implemented **curve fitting** of Modified Exponential Gaussian and compared its performance against the EFP fit using multiple metrics such as Root Relative Squared Error **(RRSE)** and **Chi-Square Error**, as well as analysis of residuals

Summer Schools

ZTF Summer School | *Zwicky Transient Facility, Caltech* — **Summer '22 and '23**

- Implemented **statistical and deep learning methods** to perform tasks such as **classification of supernovae spectra**, identification of fast-evolving optical transients, real-bogus classification of transients in ZTF data, and filtering **noise artifacts** from the ZTF alert stream
- Performed neutrino follow-up of localization from **IceCube** observatory, analyzed **3D localization data** and HEALPix maps from LIGO and performed **galaxy cross-match** to find galaxies that have a 90% volume probability for the kilonova of GW170817 - AT2017gfo
- Learnt techniques in **Bayesian Statistics** and worked with the Nuclear physics and Multi-Messenger Astrophysics (NMMA) pipeline to generate lightcurve models for **kilonovae and GRB afterglows** and create injected **electromagnetic and gravitational wave signals**
- Attended lectures on state-of-the-art transient science using ZTF, such as the Bright Transient Survey, the source classification project, and the Spectral Energy Distribution Machine

Awards and Scholarships

- Awarded the Caltech Summer Undergraduate Research Fellowship **(SURF)** for pursuing summer research at Caltech *(2023)*
- Awarded the **Mitacs** Globalink Research Internship for pursuing summer research in Canada *(2023)*
- Awarded a **gold medal** in Inter-IIT tech meet 10.0 for the astronomy problem statement *(2022)*
- Awarded a **Change of Branch** to Engineering Physics among **8 out of 1200+** students based on excellent grades *(2021)*
- Secured **99.62** percentile in Joint Entrance Examination **(JEE) Mains** among 0.92 million candidates and **96.5** percentile in **JEE Advanced** among 0.16 million candidates *(2020)*
- **3-time winner** of national level science olympiad Sastra Pratibha; invited to research institutions of DRDO, ISRO, CSIR, ICT and BrahMos *(2013 - 2016)*

Course Projects

Characterizing Non-Spinning Neutron Stars using the TOV Equation — October '23 – November '23

Advanced Astrophysics | Guide: Prof. Archana Pai, Dept. of Physics, IIT Bombay

- Extensively reviewed literature on the **Equation of State** (EoS) of neutron stars, including the maximally compact EoS and pure neutron matter EoS, understood the mass-radius relationship of neutron stars from the Tolmann - Oppenheimer - Volkoff (**TOV**) equation and studied constraints from pulsar observations and nuclear experiments
- Implemented a TOV equation solver in Python for a given EoS by stitching it to the Baym-Pethick-Sutherland neutron star **crust EoS** and solving the coupled differential equations to obtain **mass-radius curves**

Estimating Parameters of Binary Black Hole Mergers — October '22 – November '22

Gravitational Wave Physics | Guide: Prof. Archana Pai, Dept. of Physics, IIT Bombay

- Performed parameter estimation using the **Bayesian inference** library **Bilby** to obtain chirp mass, distance, inclination, geocent time, and phase of an injected non-spinning binary black hole signal from **three detector strain** data by carefully choosing priors
- Studied **noise characteristics** of LIGO detectors and calculated the auto-spectral density and **whitened strain** using **GWpy**, which was used to estimate the chirp mass of the system using the frequency evolution from the **Q-transform** of whitened data

Calculating Distance to Host Galaxy of Supernovae — March '23 – May '23

Astrophysics | Guide: Prof. Varun Bhalerao, Dept. of Physics, IIT Bombay

- Implemented a Python pipeline to perform aperture and point spread function **photometry** and obtain the lightcurve of supernova **SN2018hna**, using optical data from GROWTH India Telescope to understand its physical properties
- Performed **image reduction** and photometry using Astropy and Aperture Photometry Tool (**APT**) and attempted curve-fitting the lightcurve using the Python library **SNCosmo** to obtain an estimate of the **redshift** of the supernova

Modeling Active Three-Body System with Arduino — September '22 – November '22

Microprocessors | Prof. Pradeep Sarin, Dept. of Physics, IIT Bombay

- Solved coupled differential equations describing a system of three **interacting active particles** in a noisy environment using Arduino Uno, controlling initial system parameters using the microcontroller
- Interfaced the position and velocity output from the Arduino serial monitor to MS Excel to plot the motion of the particles in real time to observe various types of dynamic evolution

Chaos Computing — October '22 – November '22

Non-Linear Dynamics | Prof. Amitabha Nandi, Dept. of Physics, IIT Bombay

- Simulated *chaogates* - a **dynamical computing device** that can morph into different digital logic gates depending on a non-linear function - using the **logistic map and tent map** independently on Python, Arduino, and a CMOS simulation with NgSPICE
- Calculated the Lyapunov exponents and created orbit diagrams and bifurcation maps for the CMOS simulation at various bias voltages

Multiplicity Fluctuations in p-p Collisions — October '21 – November '21

Numerical Analysis | Guide: Prof. Sadhana Dash, Dept. of Physics, IIT Bombay

- Analyzed data of over **two million events** generated using PYTHIA 8 for **proton-proton collisions** at 13 TeV
- Plotted particle **multiplicity histograms**, mean, standard deviation, and scaled variance of multiplicity distributions for different multiplicity classes for accepted and rejected particles, using ROOT

Outreach Activities and Positions of Responsibility

Team Lead | **Team ANYmation, IIT Bombay** **June '22 – Present**

An all-student team of 15 developing physically accurate astronomy animations

- Created the first edition of outreach and presentation renders and animation for the proposed high-energy transient mission **Daksha**, complete with aesthetic composition and lighting, presented at various national and international scientific conferences
- Working towards developing interactive simulations using **UNITY** aimed toward education and outreach
- **Mentoring** a group of 10 students in procedural astrophysics animations using **Blender** and Python as part of Krittika Summer Projects 2022 by the Astronomy Club of IIT Bombay

Volunteer | **Krittika** **June '21 – August '22**

The Astronomy Club of IIT Bombay

- Created **Python problem statements** and solutions for multiple events and projects, including Krittika Summer Projects 2021 and 2022 and helped in organizing a **lecture series** delivered by science communicators and professors of astronomy
- Assisted in astronomy outreach efforts of the club by designing social media posts highlighting interesting astronomical phenomena and conducting **stargazing sessions** using Newtonian and Equatorial telescopes, covering Deep Sky Objects (**DSOs**) and planets
- Helped organize the Krittika Summer Projects 2022, an 8-week-long program aimed at **exposing students to astronomical research** and received 100+ applications along with international participation for the first time

Teaching Assistant **Jan '23 – April '23**

Classical Mechanics

- Responsible for conducting tutorials for a **class of 40 students**, guiding and mentoring them with their coursework, graded midterm and end-term exams of over 100 students
- Ensured smooth conduct of course by acting as a point of contact between students and instructors

Courses Undertaken

Physics:	Advanced Astrophysics, Astrophysics, Gravitational Wave Physics and Astronomy, Electromagnetic Theory, Condensed matter Physics, Advanced Simulation Techniques in Physics, Statistical Physics, Quantum Mechanics I and II, Waves and Optics, General Relativity, Classical Mechanics, Special Theory of Relativity
Mathematics:	Numerical Analysis, Linear Algebra, Differential Equations I and II, Complex Analysis, Differential Equations II, Calculus
Data Science:	Machine Learning, Image Processing, Computer Programming and Utilization, Programming for Data Science, Data Analysis and Interpretation, Data Structures and Algorithms

Technical Skills

Languages:	Python, C/C++, FORTRAN, SQL, ROOT
Libraries:	Astropy, NumPy, Matplotlib, SciPy, Pandas, GWpy, PyCBC, Bilby, Seaborn, Tensorflow, Keras, SymPy

References

Prof. Varun Bhalerao
Department of Physics
Indian Institute of Technology Bombay
India, 400076
✉ varunb@iitb.ac.in

Prof. Archana Pai
Department of Physics
Indian Institute of Technology Bombay
India, 400076
✉ archanap@iitb.ac.in

Prof. Mansi Kasliwal
Cahill Centre for Astronomy and Astrophysics
California Institute of Technology
United States of America, 91125
✉ mansi@astro.caltech.edu