Aswin Suresh

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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 and Minor in Data Science *GPA: 8.55/10*

Publications

1. 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", **accepted** in **Nature** (2023)
2. **A. Suresh**, V. Karambelkar and M. Kasliwal, "Automated Catalog of Long Period Variables with the Palomar Gattini-IR", manuscript under preparation

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 96% overall accuracy and a g-mean score of 0.97
- Created the training dataset for the decision tree classifier and **synthetically class-balanced** the dataset using adaptive synthetic upsampling of minority class and nearest neighbour downsampling of majority class
- Implemented a comprehensive feature set for the classifier, including Fourier amplitudes, **Gaussian process regression**, features based on periodicity of the lightcurve and morphology of the phase folded lightcurve
- Constructed a catalog of 16,000 LPVs from Gattini data and comprehensively analysed catalog features, validated it with the Gaia catalog of LPVs, and estimated the **period amplitude relation** for AGB stars
- Obtained spectra of interesting large amplitude variables predicted by the classifier 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

- Improved the **image subtraction pipeline** of GROWTH India Telescope (GIT) by masking bright sources and implementing pixel-to-pixel alignment 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`, achieving **99.14%** training accuracy and **97.2%** testing accuracy
- Developed scripts 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 and assisted in the followup of NS-BH event alerts

Observing Experience

- Carried out Target of Opportunity (**ToO**) observations, data reduction and analysis of a flaring Fast Blue Optical Transient (**FBOT**) and candidate ZTF **GRB afterglows** using GIT, in addition to observations of supernovae and nightly targets
- Assisted in GIT discovery of an **ultra-luminous** long GRB afterglow and performing photometric analysis using GRB physics

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
- Implemented deep learning models for real bogus classification of infrared transient alerts for the Wide-field Infrared Transient Explorer **(WINTER)**
- Assembled a comprehensive set of infrared variables and transients for the **first set** of WINTER observations
- Assisted in commissioning operations of WINTER for 2 weeks at the Palomar Observatory including observations on first light

Constraining Eccentricity of Binary Black Holes in Future Detectors **August '23 – Present**

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

- Generated waveforms of eccentric black hole binary systems using the EccentricTD waveform and extracted higher harmonic signatures from the Q-transform using the Power Spectral Density of **Einstein Telescope**
- Evaluated performance of effective chirp mass model, which estimates the chirp mass and eccentricity of binary black hole waveforms, in the frequency range 10 Hz to 3 Hz based on model fits to bright Q-transform pixels
- Calculated **frequency deviation metrics** by injecting waveforms covering a wide chirp mass - eccentricity parameter space to estimate the validity region of the effective chirp mass model in lower frequency regimes
- **Developed new methods** to extract bright pixels from the Q-transform and match model frequencies to actual frequencies using an **energy-weighted frequency deviation** metric
- **Constrained eccentricity** of binary black hole waveforms in low and high eccentricity regimes by estimating maximum energy along model track including scaled higher order modes

Automation and Updates of 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 Burts** in raw event data from the Cadmium Zinc Telluride Imager (CZTI) aboard AstroSat, to quantify the efficiency of CZTI data processing pipelines
- **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** Gamma-ray Coordinates Network Notices published in 2022
- Created a 40-second **animation** of **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 categorise** X-ray bursts from **Solar X-ray Monitor** aboard Chandrayaan-2 based on peak energy flux
- As part of a team of 6, led the implementation **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 a modified exponential gaussian and compared its performance against EFP fit using multiple metrics

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, fast-transient identification and **real-bogus classification** of transients in ZTF data as well as filter out **noise artifacts** from ZTF alert stream
- Performed neutrino follow-up of localisation from **IceCube** observatory and analysed **3D localisation** data and **HEALpix** maps from LIGO and performed **galaxy cross-match** to find galaxies that have 90% volume probability for **GW170817**
- Learnt techniques in **Bayesian Statistics** and worked with the nuclear physics and multi-messenger astrophysics pipeline to generate lightcurve models for **kilonovae** and **GRB afterglows** and create injected **electromagnetic and GW signals**

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 developing SuryaDrishti, a web-based application to identify and categorise X-ray bursts, 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

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 **Q-transform** of whitened data

Calculating Distance to Host Galaxy of Supernovae **July '21 – November '21**

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 astrophysical 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 **red-shift** of the supernova

Modelling Active Three-Body System with Arduino **September '22 – November '22**

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

- Solved differential equations describing a system of three **interacting active particles** in a noisy environment using Arduino Uno
- Interfaced the position and velocity output from Arduino serial monitor to MS-Excel to plot the motion of the particles in real time

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

- Performed data analysis on 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 towards 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 organising 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 endterm 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, Electromagnetic Theory, Condensed matter Physics, Advanced Simulation Techniques in Physics, Statistical Physics, Gravitational Wave Physics and Astronomy, 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

**to be completed by November '23*

Technical Skills

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

References

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