

# Subhrat Prahara

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## RESEARCH INTERESTS

- **Computational astrophysics**, specifically (magneto)hydrodynamic and N-body simulations to understand feedback, turbulence and structure formation across scales from planetary atmospheres to galaxy clusters
- **Astrostatistics and Astroinformatics**, with specific applications in galaxy evolution (intermedium turbulence along with stellar synthesis, evolution and population studies), high-energy transients and compact objects

## EDUCATION

<b>Birla Institute of Technology and Science (BITS) - Pilani University</b> <i>B.E. Mechanical Engg., M.Sc. in Mathematics - 8.1/10</i>	Hyderabad, Telangana <i>Aug 2018 - July 2023</i>
<b>Birla Bharati</b> <i>Science, CBSE Class 12 (AISSCE) - 90.25%</i>	Kolkata, West Bengal <i>2017-18</i>

## WORK AND RESEARCH EXPERIENCE

<b>Research Assistant (Dr. Francisco Villaescusa-Navarro)</b> <i>CCA, Flatiron Institute, Simons Foundation</i>	Oct 2022 – Present <i>New York, USA</i>
<ul style="list-style-type: none"><li>• Using Graph Neural Networks to infer virial masses of galaxy clusters.</li><li>• Using stellar masses, peculiar velocities, and comoving coordinates of individual galaxies as parameter space.</li><li>• Making the model geometrically invariant to rotation and translation for robust training and predictions.</li><li>• Working with the Uchuu simulation catalog to obtain the training data and the SDSS4 data releases for testing.</li><li>• We compare the mass estimates obtained against those through virial methods, caustics, x-ray profiles etc.</li></ul>	
<b>Research Assistant (A/Prof Christoph Federrath, Dr. Amit Seta)</b> <i>Mount Stromlo Observatory, RSAA, ANU</i>	July 2022 – Present <i>Canberra, Australia</i>
<ul style="list-style-type: none"><li>• Studying role of driven turbulence on MeV-GeV CR transport in turbulent ISM using MHD-PIC simulations</li><li>• Studying effect of Alfvénic and sonic Mach numbers on Larmor radius normalised against driving scales</li><li>• Calculating diffusion coefficients from temporal evolution of separation and fitting PDFs to separation distribution</li><li>• Interpreting dependence of test particle propagation on driving modes in terms of the field structure evolution</li><li>• Investigating existence of super-diffusion for given regime and possible dependence on turbulence driving modes</li></ul>	
<b>Summer Research Intern (Dr. Iair Arcavi)</b> <i>Wise Observatory, RBSSPA, TAU</i>	May 2022 – August 2022 <i>Tel Aviv, Israel</i>
<ul style="list-style-type: none"><li>• Quantification of Humphreys-Davidson limit using synthetic stellar populations and observed population data</li><li>• Generated CSPs with informed assumptions on star formation history, multiplicity and mixing</li><li>• Evolved multiple stellar evolution tracks based on observed Milky Way, SMC, and LMC compositions</li><li>• Inferred implications of massive star evolution around HD limit on high-energy transients and GW events</li><li>• Compared synthetic stellar populations with observed data to reconcile the empirical HD limit with theory</li></ul>	
<b>Research Assistant (Dr. Sayantan Auddy)</b> <i>Jet Propulsion Laboratory, NASA</i>	Oct 2021 – Oct 2022 <i>California, USA</i>
<ul style="list-style-type: none"><li>• Used Pruned Convolutional Neural Networks to interpret planet properties in extrasolar protoplanetary disks</li><li>• RT-HD physics-informed generation of synthetic data to directly apply the architecture to observational images</li><li>• Used massively parallel, GPU-driven code FARGO3D for orbital advection modeling of Hydrodynamic calculations</li><li>• Used RADMC-3D for observation-mimicking images and spectra from FARGO3D output using radiative transfer</li><li>• Co-developed Bayesially tuned classification-regression co-network predicting number of planets and their masses</li></ul>	

## TECHNICAL SKILLS

**Languages:** Python, C/C++, MATLAB, Fortran  
**Software:** OpenFOAM, Gmsh, Paraview, FEniCS, Tecplot, LaTeX, Fargo3D, Radmc, Flash4  
**Developer Tools:** Docker, OpenMP, PyCharm, Jupyter, Visual Studio Code, Sublime, Vim (wsl2 - Ubuntu)  
**Libraries:** pandas, NumPy, Matplotlib, Scikit-learn, TensorFlow, PyTorch, Seaborn, bilby

## RELEVANT PROJECTS - PHYSICS AND ASTRONOMY FOCUSED

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- Evolution of Large Scale Structure in  $F(Q)$  gravity** | *Gadget3, Simp2LPTic* Aug 2022 – Oct 2022
- Investigated anisotropic stellar solutions admitting Finch-Skea symmetry in presence of exotic matter fields
  - Specifically focused on Bose-Einstein Condensate Dark Matter, Kalb-Raymond, and  $U(1)$  symmetric Gauge fields
  - Used MCMC fitting techniques to constrain our modified gravity model against Pantheon, Hubble, and BAO data
  - Used N-body simulations to model structure evolution Dark and Baryonic Matter+DE scenarios in obtained model
- Accretion around models of exotic wormholes** | *Gyoto, Mathematica* April 2022 – July 2022
- Studied spherically symmetrical wormhole solutions probing accretion dynamics around special WH models
  - Studied specific cases of Schwarzschild, Reissner-Nördstrom, and Damour-Solodukhin (DS) wormholes
  - Obtained test-particle orbital solutions using normalisation by  $\mathcal{L}^2$  effective potential to model accretion disks
  - Performed ray-tracing to obtain synthetic images analysing the photon sphere for both thin and thick disk cases
  - Analysed accretion jet properties and microlensing of the radiative fluid sphere due to wormhole curvature
- Dense Matter EoS in Neutron Stars using Bayesian Analysis** | *Python* Jan 2022 – May 2022
- Studied about the development of states with depth inside a Neutron Star from a Quantum Mechanical perspective
  - Studied Bayesian Statistical techniques along with associated practices such as Nuisance Parameter classification.
  - Applied bayesian techniques to infer radius and tidal deformability (TD) of PSR J0740+6620 using NICER data
  - Employed parabolic expansion-based parametrization around piece-wise polytrope for nuclear saturation density
  - Compared radius and dimensionless TD from above against a that predicted by symbolic regression inferred model
- Accelerated expansion of the universe in modified gravity** | *Mathematica* Jan 2022 – May 2022
- Took given metrics such as FLRW to obtain Christoffel symbols and the Ricci tensor
  - Obtained non-metricity and superpotential tensor for each metric case
  - Found the energy-momentum tensor for the selected combination of perfect fluid and metric tensor model
  - Explored and reviewed non-ideal effects such as Anisotropy and Chaotic Behaviour in  $f(R,T)$  and  $f(Q)$  gravities
- Mechanical study of waves in heterogeneous medium** | *MATLAB, Mathematica* Apr 2021 – Dec 2021
- Studied the impact of inhomogeneity associated with the medium on the propagation of torsional waves
  - Modelled torsional wave propagation, specifically phase velocities under impact of initial stress
  - Deduced displacements in a multi-material medium and found the closed form dispersion relation using BVPs
  - Studied the effect of imperfections between interfaces of two distinct materials on phase and group velocity

## PEER-REVIEWED PUBLICATIONS

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- O. Sokoliuk, S. Arora, S. Praharaj, A. Baransky, P.K. Sahoo, **On the Impact of  $F(Q)$  gravity on the Large-Scale Structure**, Monthly Notices of the Royal Astronomical Society, Volume 522, Issue 1, June 2023, Pages 252–267 (2023)
- O. Sokoliuk, S. Praharaj, A. Baransky, P.K. Sahoo, **Accretion flows around exotic tidal wormholes. I. Ray-tracing**, Astronomy & Astrophysics (A&A), 665 (2022) A139, (Impact factor 6.240), EDP
- S. Kumawat, S. Praharaj & S.K. Vishwakarma, **Dispersion of torsional surface waves in a threefold concentric compounded cylinder with imperfect interface**, Waves in Random and Complex Media (2022), Taylor & Francis
- Chaitanya Peshin and Subhraj Praharaj, **Design of powertrain of an off-road racing vehicle**, AIP Conference Proceedings 2358, 050026 (2021) - 2<sup>nd</sup> International Conference on Manufacturing, Material Science and Engineering

## MANUSCRIPTS IN PREPARATION/REVIEW

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- S. Praharaj, S. Auddy, R. De, M.K. Lin, **DPNNet-2.0. II. Predicting planet masses from synthetic images of proto-planetary disks using Convolutional Neural Networks**
- S. Praharaj, A. Seta, C. Federrath, **The role of turbulence driving modes in cosmic ray diffusion**

## EXTRA-CURRICULARS WITH KEY ACHIEVEMENTS

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### **Spaceport America Cup - Vice Captain**

2019 – 2021

*Experimental Sounding Rocket Association*

*Las Cruces, NM*

- Among only 4 Indian and 150 international teams to qualify for finals. Honourable mention for our science payload

### **SAE BAJA India - Captain**

2019 – 2021

*Society of Automotive Engineers*

*Punjab, India*

- First rank among new teams, 10th overall in the presentation round. Finished inside top 25%ile in the static round

### **National Service Scheme**

2019 – 2020

*Ministry of Youth Affairs and Sports*

*BITS Pilani chapter*

- Worked on events to generate awareness on poor living conditions in old-age homes and orphanages