Subhrat Praharaj

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Research Interests

- **Computational astrophysics** and **Astro-statistics**, with specific applications in high-energy astrophysics and astro-particle physics using large-scale GR-MHD and PIC simulations along with radiative transfer. Also interested in application and addition of Machine Learning methods to improve existing computational pipelines.

Education

Birla Institute of Technology and Science (BITS) - Pilani University Hyderabad, Telangana
B.E. Mechanical Engg., M.Sc. in Mathematics - 8.1/10 Aug 2018 - July 2023

Birla Bharati Kolkata, West Bengal
Science, CBSE Class 12 (AISSCE) - 90.25% 2017-18

Work and Research Experience

PhD Researcher (Prof. Dr. S.B. Markoff) Oct 2023 – Ongoing
Anton Pannekoek Instituut, Universiteit van Amsterdam - Onsite Paid Amsterdam, Netherlands
- Will perform high-performance computations to understand disk-accretion processes associated with Black Holes.
- Will aim to theoretically reproduce multi-messenger observations associated with specific Black Holes.
- Will develop massively parallel and highly-scaleable GPU codes to resolve kinetic scale processes in such systems.
- Will work on adding more data-driven methods revolving around Machine Learning to the existing pipelines.
- Will work on understanding the individual interplay of disk-level systems to reproduce system level dynamics.

Research Assistant (Dr. Francisco Villaescusa-Navarro) Oct 2022 – Sep 2023
CCA, Flatiron Institute, Simons Foundation - Remote Unpaid New York, USA
- Used Graph Neural Networks to infer virial masses of galaxy clusters.
- Used stellar masses, peculiar velocities, and comoving coordinates of individual galaxies as parameter space.
- Made the model geometrically invariant to rotation and translation for robust training and predictions.
- Worked with the Uchuu and CAMELS simulation catalog to obtain the training data.
- Compared the mass estimates obtained against those through virial methods, caustics, x-ray profiles etc.

Research Assistant (A/Prof Christoph Federrath, Dr. Amit Seta) July 2022 – Aug 2023
Mount Stromlo Observatory, RSAA, ANU - Remote Unpaid Canberra, Australia
- Studied role of driven turbulence on MeV-GeV CR transport in turbulent ISM using MHD-PIC simulations
- Studied the effect of Alfvenic and sonic Mach numbers on Larmor radius normalized against driving scales
- Calculated diffusion coefficients from temporal evolution of separation and fitting PDFs to separation distribution
- Interpreted dependence of test particle propagation on driving modes in terms of the field structure evolution
- Investigated existence of super-diffusion for given regime and possible dependence on turbulence driving modes

Summer Research Intern (Dr. Iair Arcavi) June 2022 – August 2022
Wise Observatory, RBSSPA, TAU - Onsite Unpaid Tel Aviv, Israel
- Quantification of Humphreys-Davidson limit using synthetic stellar populations and observed population data
- Generated CSPs with informed assumptions on star formation history, multiplicity, and mixing
- Evolved multiple stellar evolution tracks based on observed Milky Way, SMC, and LMC compositions
- Inferred implications of massive star evolution around HD limit on high-energy transients and GW events
- Compared synthetic stellar populations with observed data to reconcile the empirical HD limit with theory

Research Assistant (Dr. Sayantan Auddy) Oct 2021 – Oct 2022
Jet Propulsion Laboratory, NASA - Remote Unpaid Pasadena, USA
- Used Pruned Convolutional Neural Networks to interpret planet properties in extrasolar protoplanetary disks
- RT-HD physics-informed generation of synthetic data to directly apply the architecture to observational images
- Used massively parallel, GPU-driven code FARGO3D for orbital advection modeling of Hydrodynamic calculations
- Used RADMC-3D for observation-mimicking images and spectra from FARGO3D output using radiative transfer
- Co-developed Bayesially tuned classification-regression co-network predicting number of planets and their masses

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 - Credited project-based courses

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 Christophell 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

- 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 Subhrat Praharaj , **Design of powertrain of an off-road racing vehicle**, AIP Conference Proceedings 2358, 050026 (2021) - 2nd International Conference on Manufacturing, Material Science and Engineering

Extra-Curriculars with Key Achievements

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