

HARSHDA SAXENA

Final year undergraduate, Indian Institute of Technology Bombay

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RESEARCH INTERESTS

Theoretical Physics, particularly in the fields of Astrophysics, Cosmology, and Gravitation.

EDUCATION

Indian Institute of Technology Bombay

July '19 - Present

- **Major degree (with Honors):** Bachelor of Technology in Engineering Physics
CPI: 9.78/10, **Honors CPI:** 10/10
- **Minor degree:** Dept. of Mathematics, **Minor CPI:** 10/10

ETH Zürich

Spring '22

Completed a Semester Exchange at ETH Zürich with the relevant courses:

Theoretical Cosmology (Grade: 6/6), Symmetries in Physics (Grade: 6/6), Differential Geometry II (Grade: 6/6), Electrodynamics (Grade: 5.75/6)

RESEARCH EXPERIENCE

Non Linear Cosmic Structure Formation

Dec '21 - Present

Prof. Matthias Bartelmann | Institute for Theoretical Physics | Heidelberg University

- Studied the details of **Kinetic Field Theory (KFT)**, an analytic field theory of structure formation in classical particle ensembles and its applications in **analyzing cosmic structures**
- Applied the formalism of KFT to **original calculations** of the non-linear cosmic power spectrum for a variety of **modified gravity models incorporating screening** mechanisms such as the Chameleon model, Vainshtein screening, k-mouflage mechanism, and Yukawa suppression
- **Generalized the code** developed by the research group to include parametrizations of modified gravity models involving modified Poisson equations into a scale dependent effective gravitational constant to obtain the **non-linear power spectra** for a variety of models, as given [here](#)

Black Hole Mass Gap

Sept '20 - Present

Prof. Vikram Rantala | Dept. of Physics | Indian Institute of Technology Bombay

- Analysing the effect of **exotic Beyond Standard Model particles on the $^{12}C(\alpha, \gamma)^{16}O$ rate**, the major parameter impacting the lower edge of the **Black Hole Mass Gap (BHM)**
- Studied the **effects of various astrophysical and particle physics parameters** like metallicity, rotation, convective overshoot, wind mass loss, nuclear reaction rates, neutrino physics, dark matter annihilation, and axionic emissions on the lower edge of the BHM
- Simulated the effects of these parameter dependencies on the blackhole masses using the **1D stellar evolutionary code MESA** and its PPISN test suites and analyzed the region of dynamical instability in massive stars in the core temperature and density plane using **Mathematica**

Quantum Gravity and Trace Dynamics

Dec '21 - Feb '22

Prof. Tejinder Pal Singh | Dept. of Astrophysics | Tata Institute of Fundamental Research

- Reviewed **Teleparallel gravity, an equivalent construction of general relativity** in the tetrad formalism, and the resulting Poincare algebra in the phase space of the theory
- Studied the details of a Quantum Gravity candidate, which utilizes matrix valued Lagrangian dynamics on an octonionic spacetime evolving in Connes time
- Studied the details of the **emergence of standard model symmetries from the $C \otimes O$ algebra** from [C. Furey's thesis](#)

Differential Topology

May '21 - July '21

Prof. Sugata Mondal | Dept. of Mathematics | Tata Institute of Fundamental Research

- Studied **Gullemin & Pollock** for an introduction to manifolds, transversality and its applications in proving stability theorem, Sard's Theorem, **Morse Theory**, classification of one and two Manifolds, **Jordan Brouwer Separation Theorem**, Borsuk Ulam Theorem and others
- Studied **oriented intersection theory**, specifically Lefschetz fixed point theory, Poincare-Hopf theorem, differential forms, exterior derivatives, Stokes Theorem and **integration on manifolds**

ACADEMIC ACHIEVEMENTS

- Secured Department Rank **2** among 51 students in Engineering Physics (Present)
- Selected in **Top 2** students from IITB for a **Semester Exchange at ETH Zurich** (Spring '22)
- Awarded the **DAAD-WISE scholarship** for a fully funded summer internship ('22)
- Among the **Top 28 students selected across India** for the Visiting Students Research Programme conducted by the School of Mathematics, Tata Institute of Fundamental Research ('21)
- Secured an **AP** grade in Numerical Analysis, awarded to the **top 6 in 642** students (Spring '21)
- Achieved a **perfect 10** Semester Point Index (SPI) in semesters 4 and 5 ('21)
- Awarded the **Kishore Vaigyanik Protsahan Yojana Fellowship (KVPY)** awarded by the Department of Science and Technology, Government of India ('18)
- Awarded the **INSPIRE scholarship** for ranking among top 1% of students appearing for the Higher Secondary Education (HSC) board examination ('19)

SELECTED COURSE AND CLUB PROJECTS

PT Symmetric Photonic Heterostructures

Jan '21 - May '21

Prof. Anshuman Kumar | Course Project | Waves and Oscillations

- Studied *PT* symmetric **Hamiltonian's in optics**, the resulting S and transfer Matrices, the **generalized unitarity relations** and the resulting conservation relations
- Reproduced plots of **Anisotropic Transmission Resonances** using Abeles Matrix Formalism, *PT* symmetry breaking transitions, and phase transition boundaries using python, and studied the **application of such heterostructures** in CPA laser points & unidirectional invisibility

Data Analysis of Event Characteristics in p-p collisions

Sept '20 - Dec '20

Prof. Sadhana Dash | Course Project | Data Analysis and Interpretation

- Analyzed the data generated by the Pythia 8 Monte Carlo event generator for the interactions of protons in **2 million proton-proton collisions at 13TeV using ROOT** (by CERN)
- Reproduced the plots for the normalized frequencies of the **relative angle**, **scaled densities**, and the **density of the scalar sum over the momenta** of particles as a function of lead momentum in the toward, away and transverse regions for various multiplicity classes

Cosmology and Dark Matter

April '20 - June '20

Summer of Science | Maths and Physics Club | Indian Institute of Technology Bombay

- Studied the **mathematical foundations of general relativity**, Einstein tensors, Bianchi identities, and the **applications of general relativity** such as the production and detection of gravitational waves, Schwarzschild and Kerr Blackholes, and the metric around relativistic stars

Simulating Kirkwood Gaps

July '21 - Sept '21

Krittika Summer Projects | The Astronomy Club | Indian Institute of Technology Bombay

- Implemented of a **Monte Carlo simulation to evolve large distributions of asteroids** around the sun to simulate the **emergence of Kirkwood gaps** in the asteroid belt
- Studied the solutions of the **general n-body problem** using exactly **conservative integrators**

Star Hopping Guide

April '20 - July '20

Krittika Summer Projects | The Astronomy Club | Indian Institute of Technology Bombay

- Facilitated the **development of a portal to aid DSO observation**, and created a **star hopping mechanisms for 104 Messier Objects** to aid the process of finding them in the sky
- Coordinated with 4 subgroups working on **databases, data plotting, user and editor interfaces and hopping mechanisms**, and helped them integrate their work into one portal

TECHNICAL SKILLS

Languages : C++, Python, HTML, Fortran, L^AT_EX

Software : Wolfram Mathematica, MESA, Root, Origin, SAOImage DS9, Quartus

Libraries : Numpy, Scipy, Astropy, Xact, matplotlib, Qiskit

Operating Systems : Linux, Windows

KEY COURSES UNDERTAKEN

- **Physics** : Theoretical Cosmology, Symmetries in Physics, Advanced General Relativity, Gravitational Wave Physics and Astronomy, Quantum Mechanics I,II, Quantum Field Theory, General & Special Relativity, Electrodynamics, Introduction to Nuclear Particle Physics, Data Analysis
- **Mathematics** : Differential Geometry I & II, Basic Algebra, General Topology, Numerical Analysis, Real & Complex Analysis, Linear Algebra, Ordinary & Partial differential equations
- **Miscellaneous**: Computer Programming, Optics Lab, Microprocessors, Digital Electronics

POSITIONS OF RESPONSIBILITY

Teaching Assistant, PH107: Quantum Physics and Applications *Nov '21 - Feb '22*

- Selected for the position of a Teaching Assistant for an introductory quantum mechanics course taken by first year undergraduates, and solved **conceptual doubts for over 350 students**, assisted in making and presenting solutions to tutorial problems, and grading examinations

Outreach, Convener: Krittika, The Astronomy Club of IITB *April '20- April '21*

- Part of a team of 10, responsible for organizing several **institute-wide events** such as projects, lectures, reading clubs, workshops, group discussions, and others, for astronomy enthusiasts
- Organized and moderated the **Techfest Astrophysics Workshop for over 200 participants** pan-India, covering theoretical and hands on experience for topics like **Gamma Ray Bursts, Gravitational Wave Analysis and Multimessenger Astronomy**

Mentor, Student Projects : Math and Physics Club, IITB

- **Mentored on Differential Topology** under Winter of Puzzles and developed problem statements to select the Top 5 from over 200 applicants, and created and assessed their assignments
- Mentored 5 applicants each year on a variety of topics such as **Cosmology and Dark Matter, Astrophysics, and General Relativity**, under the Summer of Science program

EXTRA CURRICULARS

Volunteer Work *May '20 - present*

- Working as a core member in **Operations and Marketing** under the initiative **URHope-Foodbank** and helped distribute over **9 Lac ration kits and cooked meals**
- Assisted in **immediate relief during floods**, blanket distribution, **stationary distribution to underprivileged kids**, and contributing to **enhancing the skill set of the differently abled** by providing them culinary education in partnership with multiple other NGO's
- Worked in databasing under **Mission Aahan Vahan** and assisted and coordinated with over **2700 migrant workers during the COVID-19 pandemic** with filling government forms to avail Shramik Trains to reach their home states during the migrant crisis
- Working as an active volunteer for **Saathi (the LGBTQIA+ Resource group for IIT Bombay)**, to advocate for a more inclusive campus and in ideating multiple events

Sports

- Competed at the **State Level** for Baseball in 2016, and got **shortlisted for Nationals**
- Part of the **IITB Women's Basketball team**