

# Apurv Keer

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## Research Interest and Experience

My academic focus centers on **Quantum Gravity** and **Black Hole Physics**, with a strong foundation in General Relativity, Classical Mechanics, Quantum Field Theory, and Quantum Mechanics. Currently, my research is dedicated to the investigation of Quantization within the realm of 5D Gauss-Bonnet Gravity. Additionally, I possess a keen interest in **Computational Physics** and boast proficiency in programming languages such as Python, C++ (with a specialization in Object Oriented Programming), Fortran, Mathematica, and ROOT (CERN).

## Education

### Indian Institute of Technology Bombay

Bachelor of Technology, Department Of Physics

Majoring in **Engineering Physics**, while pursuing an **Honors** in Physics

GPA: 8.4/10

'21 – Present

## Scholastic Achievements

Attained an impressive **9.47 SPI** out of 10 during the **Spring semester of 2022-23** at IIT Bombay ('23)

Attained an exceptional **99.15** percentile ranking in the **JEE - Main**, surpassing over **1 million** candidates ('21)

Secured a **98.11** percentile in the **JEE - Advanced**, standing out among **0.14 million+** candidates ('21)

Demonstrated excellence with a **99.86** percentile in the **MHT CET**, outshining **0.41 million+** candidates ('21)

## Key Projects

### Quantization in 5D Gauss-Bonnet Gravity

Jan '23 – Present

Guide: Prof. Shankaranarayanan S, Department of Physics, IIT Bombay

- Working on a **5D Gauss-Bonnet gravity action** obtained from **Kaluza Klein dimensional reduction**
- Leaning to perform Relativistic and Field Theory related calculations in **xAct Mathematica** and **Cadabra 2**
- Searching for quantum corrections resulting from expansion about a background classical solution to the 5D field equations and examining the effect of the **quantum fluctuations** on the "physical" space-time
- Obtained field equations of **Boson Stars (Q-Balls)** in 4D EGB gravity based on Glavin and Lin's approach of rescaling the Gauss-Bonnet constant to study the dynamical effects on the Gauss-Bonnet term

### Hands on Computational Physics : Raytracing in Curved Spacetime

June '23 – July '23

Season Of Code, Web and Coding Club(WnCC), IIT Bombay

[Source](#)

- Explored diverse numerical analysis methodologies for computational physics using **Python** and **Fortran**
- Executed projects encompassing the **visualization** of Poisson's equation solutions, Hydrogen atom eigenstate **wavefunctions** and eigenvalues, and resolution of **time-evolution systems** for non-linear oscillators
- Engineered a **C++ raytracer** tailored to simulate a curved spacetime environment which entailed the numerical solutions of geodesics encircling a **Schwarzschild black hole**, leading to visual depictions of phenomena such as **accretion disks** and gravitational lensing effects, including the formation of an **Einstein ring**

### Exploring Hertzsprung-Russell Diagrams

Aug '22 – Nov '22

Computational Astronomy Bootcamp, Kritika: The Astronomy club of IIT Bombay

[Source](#)

- Engaged in a two-week virtual workshop on **computational astronomy**, hosted by Kritika Astronomy Club
- Focused intently on grasping the intricacies of **Stellar Evolution** and **Classification**, exploiting observational data using **data science modules** for array manipulation to statistically deduce outcomes and gain insights
- Spearheaded an intricate data analysis project centered around the NGC 2808 cluster, drawing from the extensive HST UV Globular Cluster Survey (**HUGS**) **dataset**, encompassing over **100 million** data points.

- Accomplishments included constructing the **Hertzsprung-Russell Diagram** of the cluster and producing an insightful visualization depicting **stellar positions** based on RA and Dec values from the dataset

## Other Projects

### Cosmology And Dark Matter

May '22 – July '22

Summer Of Science, Maths, And Physics (MnP) Club, IIT Bombay

[Report](#)

- Acquired a foundational understanding of Einstein's General Relativity through **Reimannian geometry** and **manifolds** and also through the application of the **variational principle** to the Einstein-Hilbert action
- Focused on its cosmological implications, particularly in relation to mathematical frameworks of the universe within the context of **FLRW cosmology**, like the Friedmann equations, Hubble's law, red-shift effects, etc.
- Engaged in theoretical exploration of the diverse epochs of the universe spanning from the Big Bang while investigating evidence and an array of potential **dark matter** candidates and **dark energy** models
- Developed an exhaustive LATEX report and an interactive presentation, intended as valuable introductory points of reference for others in the field of General Relativity, Cosmology, and dark matter

### Astrophysically Accurate Animations

June '22 – Sept '22

Krittika Summer Project, Krittika: The Astronomy club of IIT Bombay

[Report](#)

- Created a **Binary Black Hole merger simulation** using **Blender**, a powerful 3D computer graphics software
- Illustrated the merging processes and the ensuing emission of **Gravitational Waves** through visuals
- Employed **Python scripting** within Blender to precisely model the trajectories of the interacting **black holes**

### Non-Linear Dynamics in Biochemical Networks

Autumn '22

Course Project, Guide: Prof. Amitabha Nandi, Department of Physics, IIT Bombay

[Report](#) | [Source](#)

- Worked in a team of 4 on the basic building blocks of dynamic behavior in **non-linear control systems**
- Studied how simple signaling pathways can be embedded in networks using positive and negative feedback to generate **complex behaviors** like toggle switches and oscillators using **mathematical techniques**
- Reproduced graphs from a research paper about Sniffers, buzzers, toggles, and blinkers: dynamics of regulatory and signaling pathways in the cell by solving differential equations using **Runge-Kutta algorithms**

### Underlying Events in Proton-Proton Collisions

Autumn '22

Course Project, Guide: Prof. Sadhana Dash, Department of Physics, IIT Bombay

[Report](#) | [Source](#)

- Engaged with an extensive dataset comprising **two million** events within **p-p collision** systems, which were generated through the utilization of Pythia 8, a Monte Carlo event generator
- Methodically analyzed the data across **six distinct multiplicity** categories, effectively categorizing particle distributions into **three distinct regions**. This classification was based on the azimuthal angle of the leading jet's direction, while concurrently investigating the distributions of **transverse momentum** and **rapidity**
- Leveraged the **ROOT** software to effectively generate Course Projects, thereby **plotting distributions** across varied regions and multiplicity classes and extracting and interpreting valuable trends from the data

### High-Frequency LED Clock

Spring '22

Course Project, Guide: Prof. Pradeep Sarin, Department of Physics, IIT Bombay

[Report](#) | [Source](#)

- Developed a **highly accurate digital clock** utilizing an ,Field Programmable Gate Array, **FPGA board**, achieving precise timekeeping through the utilization of our meticulously designed **Verilog-HDL** code
- Incorporated counters and buttons for an **input mode**, empowering users to define their **desired time**
- Built a **LED display unit** for the clock using effectively linked separate 7-segment displays and interfaced it to showcase multiple modes on a **single screen**, thus enhancing the versatility and functionality of the clock

### Bubble Trouble Game

Autumn '21

Course Project, Guide: Prof. Parag Kumar Chaudhari, Department of CSE, IIT Bombay

[Source](#)

- Executed a series of feature implementations and performance enhancements within a captivating **bubble shooting game** by proficiently utilizing **C++** programming language in a simplified version of Code::Blocks
- Skillfully leveraged **Object-Oriented Programming** principles like classes and structures to streamline and enhance the game's intricacies, resulting in a more engaging and dynamic experience for the user
- Demonstrated a commitment to user satisfaction by integrating informative messages via strategically placed **conditional statements** and **looping structures** making the game more intuitive and enjoyable for players

## Teaching Assistantships and Mentorships

### PH111 : Classical Mechanics

Spring '22

Department of Physics, IIT Bombay

- Provided guidance and support to a cohort of **38 first-year students**, aiding them in resolving **tutorial problems** and addressing **general inquiries** while effectively tackled problem-solving tasks encompassing subjects like **Newtonian Mechanics**, **Planetary Orbital Mechanics**, and **Special Theory of Relativity**

### MA108 : Differential Equations

Spring '22

Department of Mathematics, IIT Bombay

- Provided guidance to a group of **40 freshmen** by aiding them in **solving tutorial problems** and addressing **general doubts** involving the resolution of **Ordinary Differential Equations (ODEs)** through techniques such as undetermined coefficients, variation of parameters, Laplace transforms, and convolutions

### Mentor, Summer of Science : Cosmology and Dark Matter

May '23 – July '23

Maths and Physics(MnP) Club, IIT Bombay

- Mentored **3 freshers** to study Cosmology and Dark Matter as a part of the Summer Of Science project by provided them with materials to study **mathematical models of the universe** and **dark matter candidates**

## Technical skills

<b>Languages</b>	C++, Fortran, Python (Numpy, Pandas, Scipy, Matplotlib, Astropy), HTML/CSS, Verilog-HDL
<b>Softwares</b>	Blender, $\text{\LaTeX}$ , ROOT, LTSpice, AutoCAD, Gnuplot, Arduino IDE, Mathematica, CUDA Toolkit

## Courses Undertaken

<b>Physics</b>	Special Relativity, Advanced General Relativity*, Classical Mechanics, Electromagnetism, Relativistic Quantum Mechanics & Quantum Field Theory*, Waves & Oscillations, Data Analysis & Interpretation, Non-Linear Dynamics, Thermal Physics, Photonics*
<b>Mathematics</b>	Linear Algebra, Complex Analysis, Differential Equations, Calculus, Numerical Analysis
<b>Miscellaneous</b>	Introduction to Electronics, Digital Systems, Electronics Lab(Analog, Op-amp, Digital and Microprocessor*), Computer Programming and Utilization

## Extracurriculars

Mentored **4 freshers** in a **standup comedy** competition Laughter Riots 3.0 by Comedy Cons, IIT Bombay ('23)  
 Awarded **Student Of The Year** by **Times Of India NIE** for securing **first** rank in the school ('19)  
 Appointed as the school **Head Boy**, **St. John's High School**, for **three consecutive years** ('17 - '19)  
 Placed **4th** in **Mumbai** and was selected for **State Level Suryanamsakar** competition ('16)  
 Learned **Drums** through **Introductory Music Learning** Programme by **IIT Bombay** ('22)