Rishi **Raj**

Graduate Researcher · Theoretical Physics

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Education

Sorbonne Université — *Paris, France*

Doctor of Philosophy (PhD) — *Oct 2023 - Present*

- Carrying out doctoral research work on BPS Black Holes and Donaldson-Thomas invariants at the Laboratoire de Physique Théorique et Hautes Energies (LPTHE).

Indian Institute of Technology (IIT) Madras — *Chennai, India*

BS (Hons) and MS in Physics with a minor in Mathematics — *Aug 2018 - Jul 2023*

- Received the 'Mr S. Venkitaramanan, I.A.S Retd' prize for securing the highest CGPA during the academic year 2021-22
- Received the 'Electronics For You' prize for securing the highest CGPA during the academic year 2020-21

Fellowships and Achievements

Charpak Lab Fellowship — *Paris, France*

Embassy of France in India — *May - July 2023*

- Selected among the top few candidates to receive funding for a research internship in France.

Alumni Travel Grant — *Chennai, India*

Indian Institute of Technology Madras — *June - July 2022*

- Received financial support for financing a research trip to Paris, France.

KVPY Fellow — *Bangalore, India*

Department of Science and Technology (DST), Govt. of India — *Aug 2018 - Present*

- Awarded for ranking 332 all India in a competitive national exam.

National Initiative on Undergraduate Sciences (NIUS) Fellow in Physics — *Mumbai, India*

Homi Bhabha Centre for Science Education, TIFR — *May 2019 - Jan 2020*

- Selected among India's top research undergraduates for a fast-paced science camp leading up to research projects.

Joint Entrance Exam (JEE) — *Delhi, India*

Conducted by IIT Kanpur (Advanced) and CBSE (Main) in 2018 — *May 2018*

- Ranked 1398 nationally (among over 100K shortlisted from JEE Main) in JEE Advanced and 332 in JEE Main, entrance exams to top STEM undergraduate programs in India.

Research Experience

High Energy Theory

Random Matrices and Black Holes — *Chennai, India*

String Theory Group, IITM[1] and Vishnu Jejjala, U. Witwatersrand — *Jan 2023 - Present*

- Obtained and examined, numerically, classical solutions of the D0-brane matrix model.
- Conjectured a particularly simple form for the time distribution of the matrices, namely a set of independent and identical scaled traceless GUEs for large matrix size. We found the scale factor's precise form through various numerical methods.
- Studied deviations away from random matrix behavior.

Machine Learning Holographic Thermalization — *Chennai, India*

String Theory Group, IITM and Vishnu Jejjala, U. Witwatersrand — *Oct 2022 - Dec 2022*

- Developed high-accuracy neural networks to learn basic features of non-equilibrium processes on asymptotically AdS geometries, such as the areas and positions of the event and apparent horizons starting from parameters describing numerical solutions of Einstein's equations.

Black Hole microstates in Matrix models — *Bangalore, India*

String Theory Group, IITM and Vishnu Jejjala, U. Witwatersrand — *Aug 2020 - May 2022*

- Developed efficient numerical techniques to perform classical and quantum mechanical simulations of the M-theory matrix model for relatively large matrix sizes.

[1] Ayan Mukhopadhyay, Tanay Kibe, Sukrut Mondkar

Wall Crossing Phenomena in $\mathcal{N} = 2$ SUGRA

Jussieu, Paris

Internship supervised by Boris Pioline at LPTHE, Sorbonne University — *Summer 2022*

- Implemented various algorithms to compute BPS indices and jumps thereof in the complexified Kähler moduli space of Calabi-Yau threefolds in $\mathcal{N} = 2$ supergravity in four dimensions.
- Identified an interesting connection between the phase space of multi-centered solutions and corresponding attractor flow trees.

Semiholographic Networks

Chennai, India

Supervised by Ayan Mukhopadhyay, IIT Madras — *Jul 2019 - Nov 2020*

- Developed a simple set of networks of scalar fields coupled with perfect fluids using the Semiholographic approach developed by the supervisor and colleagues. Studied the perturbation response of the system

Independent Research

Chennai, India

Reading projects supervised by Ayan Mukhopadhyay, IIT Madras — *Summer 2019*

- Studied the Montonen-Olive and similar duality conjectures, the Witten effect in the context of $\mathcal{N} = 4$ SYM.
- Studied modern relativistic hydrodynamics and how transport coefficients are significantly constrained by consistency requirements with thermal partition functions in QFTs in stationary background spacetimes.
- Developed a good understanding of memory effect, soft theorems, and asymptotic symmetries and their relationship in the infrared physics of quantum field theories.

Relevant Coursework

Advanced Physics

Spring 2023	**String Theory**
Spring 2023	**Advanced Particle Physics**
Spring 2022	**Quantum Field Theory I/II**
Spring 2021	**Advanced General Relativity**
Spring 2022	**Advanced topics in Quantum Computation and Quantum Information**
Fall 2022	**Advanced Statistical Physics**

Audited / Self-Study

Fall 2022	**Supersymmetry and Supergravity**
Fall 2022	**String Theory**
Spring 2022	**Conformal Field Theory**
Spring 2021	**Mathematics of Quantum Mechanics**
Fall 2020	**Geometry and Theoretical Physics**
Spring 2019	**Dynamical Systems and Chaos**

Work Experience and Positions of Responsibility

Teaching Assistant

Chennai, India

PH5060 (Physics Lab 1) — *Jul 2022 - Nov 2022*

- Taught and helped students work through various computational problems, such as understanding the phase portrait of chaotic dynamical systems, studying probability distributions, and Monte Carlo simulations.
- Took viva interviews, graded the reports, and prepared the final exam.

Music Club IITM

Chennai, India

Coordinaor — *Jul - Nov 2019*

- Worked for the student-run music club of the institute in organizing various musical events in the Fall 2019 semester and for the annual social and cultural festival of IITM, Saarang.

Horizon Club IITM

Chennai, India

Organizer — *September 2019*

- Organized and delivered four lectures titled 'Relativity from symmetries' to beginning physics enthusiasts.

Skills

Scientific Computation Mathematica · Boost C++ · GNU Scientific Library (GSL) · Python · Cadabra

Typesetting LaTeX · HTML5 / CSS3 · Google Office Suite

Programming Python · Javascript/Typescript · C / C++

Misc Git / GitHub · Statistical Inference · Discrete Data Structures and Algorithms · Machine Learning with TensorFlow