

# Vedant Bhutra

## Curriculum Vitae

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LinkedIn

### Research Interests

- Black holes in string theory
- Chern-Simons matter theories
- Field-theoretic superconductivity
- Large  $N$ ;  $AdS/CFT$
- SYK models

### Education

2019 – 2024 **Indian Institute of Science Education and Research Bhopal**, India.  
*Bachelor and Master of Science (BS-MS), Department of Physics.*  
CPI (current): 9.05/10  
Minor in Mathematics.

### Master's Thesis

2023 – 2024 **Modular forms and their applications to black holes in string theory**,  
*Supervisor: Dr. Nabamita Banerjee, Dept. of Physics, IISER Bhopal, India.*

- Studying the connection between modular forms (elliptic, Jacobi and Siegel) and other objects from number theory, such as  $L$ -functions, and the microscopic quantum description of supersymmetric black holes in string theory.
- Reviewing the physics background of extremal black holes, conformal field theory (CFT) and superstring theory, including the string compactification on  $K3 \times T^2$  and the corresponding classification of Bogomol'nyi-Prasad-Sommerfield (BPS) states.
- Aim to understand the quantum degeneracies associated with a black hole horizon, and the role of modular forms in BPS dyonic state counts and the attractor mechanism, wall-crossing phenomena, rational CFT and quantum chaos.
- Notes: [modular forms](#), [conformal field theory](#), [string theory](#).

### Projects

2023 – 2024 **Supersymmetric boundary conditions for higher spin gravity in  $AdS_3$  and droplets**,  
*Supervisor: Prof. Suvankar Dutta, Dept. of Physics, IISER Bhopal, India.*

- Studying the asymptotic dynamics of (2+1) dimensional gravity with negative cosmological constant using various sets of known boundary conditions, which reduce it to the Wess-Zumino-Witten model, and further to the Liouville field theory.
- Aim to introduce new sets of supersymmetric boundary conditions for higher spin gravity in  $AdS_3$ , where the bulk theory is formulated in terms of Chern-Simons theory.
- Also aim to study the geometric description of the collective field theory in terms of two-dimensional droplets.

2022 – 2023 **Eliashberg study of magnon-mediated superconductivity**,  
*Supervisor: Prof. Rajdeep Sensarma, Dept. of Theoretical Physics, TIFR<sup>1</sup>, Mumbai, India.*

- Reviewed field theories in condensed matter, including green's functions of quasiparticles like phonons, and the electron-phonon physics in metals. Studied the strong-coupling Eliashberg theory of superconductivity.
- Derived new set of Eliashberg equations which include various types of electron-boson interactions, and non-trivial material effects such as the presence of Rashba spin-orbit coupling.
- Finally, developed a model for magnon-mediated superconductivity in a metal via interfacial coupling to ferromagnetic insulators. Studied the properties of this model analytically and numerically.
- Notes: [Eliashberg theory](#), [modified with spin-orbit coupling](#), [magnon-mediated superconductivity](#).

- 2022 **Interplay of charge density wave and  $s$ -wave superconducting orders**,  
*Supervisor: Prof. Amit Ghosal, Dept. of Physical Sciences, IISER Kolkata, India.*
- Studied the dynamics of charge density wave order and  $s$ -wave superconducting order in clean and disordered systems. Simulated the problem using an attractive Hubbard model on a square lattice.
  - Aimed to extend the numerics to more complex but realistic systems, such as transition metal dichalcogenides, which have triangular lattices and multiple layers.

### Reading Projects

- 2023 **Chern-Simons gauge theory on 3-manifolds**,  
*Supervisor: Prof. Suvankar Dutta, Dept. of Physics, IISER Bhopal, India.*
- Studying Chern-Simons theories for Abelian gauge fields, including 3D Maxwell-Chern-Simons  $U(1)$  gauge theory, quantization of flat connections on a torus, and Chern-Simons theories for non-Abelian gauge fields.
  - Also studying the Wess-Zumino-Witten model, rational CFT and general topological field theories. Primarily followed [TASI lecture notes by Prof. Gregory Moore](#).

- 2021 – 2022 **BCS theory of superconductivity and multi-layered graphene**,  
*Supervisor: Prof. Rajdeep Sensarma, Dept. of Theoretical Physics, TIFR, Mumbai, India.*
- Studied literature on many body quantum theory, advanced statistical physics, interacting degenerate gases, Fermi liquid theory, and the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity.
  - Further studied electronic structure theory, including tight-binding models and density functional theory, and looked at applications in the study of monolayer and twisted multi-layer graphene.
  - Lastly, studied unconventional superconductivity via alternate pairing mechanisms, generalized BCS theory ( $s$ -wave,  $p$ -wave, and  $d$ -wave superconductivity), and Migdal's theorem.

### Course Projects

- 2023 **Quantum spin Hall effect in graphene**, *Advanced Topics in Theoretical Condensed Matter*.  
Presented the Kane-Mele model (Phys.Rev.Lett. 95, 226801 (2005)), in which additional terms are considered for spin-orbit coupling in the Hamiltonian of the quantum Hall effect problem for graphene. [Presentation](#).
- 2023 **Cartan classification of root systems and Dynkin diagrams**, *Lie Groups and Lie Algebras*.  
Explained the theory of root systems, Dynkin diagrams and Coxeter graphs, their classification, and applications in the theory of semisimple Lie algebras. [Notes](#).
- 2022 **Lattice Boltzmann modeling of fluids**, *Numerical Methods and Programming*.  
Modeled fluid flow around obstacles of different shapes, varying parameters such as Reynolds number. Observed the relationship between these and presence of laminar flow, vortices, and turbulence. [Report](#).
- 2021 **Numerical analysis of coupled pendulums and blocks**, *Computational Physics*.  
Modeled a complicated system of pendulums coupled by springs and attached by rods to blocks which were periodically driven. The analysis was done analytically and numerically. [Report](#).

### Scholarships

- 2019 – 2024 INSPIRE<sup>2</sup> Scholarship, *Dept. of Science & Technology, Govt. of India*.  
2020 – 2022 NIUS<sup>3</sup> (Physics) Fellowship, *Homi Bhabha Centre for Science Education – TIFR, India*.

### Achievements

- 2023 Best delegate at Model United Nations, 2023, IISER Bhopal.  
2021 First position at Model Solvay Conference, 2021, IISER Bhopal.

### Schools, Courses & Workshops

- 2023 Observable Algebras in Quantum Field Theory and Gravity, *IIT Mandi*.

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<sup>1</sup>Tata Institute of Fundamental Research

<sup>2</sup>Innovation in Science Pursuit for Inspired Research

<sup>3</sup>National Initiative on Undergraduate Science

- 2023 Advanced General Relativity, *ICTS-TIFR, Bengaluru.*
- 2021 Simulation and Modeling of Natural Processes, *University of Geneva.*
- 2021 Topological Phenomenon in Condensed Matter, *ICTP, Trieste.*
- 2021 Introductory Summer School on Astronomy and Astrophysics, *IUCAA, Pune.*
- 2020 Data-driven Astronomy, *University of Sydney.*
- 2020 Graph Theory; Mathematical Thinking in Computer Science, *U.C. San Diego.*
- 2020 Workshop on Gravitational Waves and Electromagnetic Transients, *IIT Bombay.*

## Skills

Programming Python, C, C++, Julia, XMDS2  
 Software Mathematica, MATLAB, L<sup>A</sup>T<sub>E</sub>X, SageMath

## Activities

- 2021 – 2023 Member of student research group for astronomy, *IBAC-RG.*
- 2022 Student representative at *Center for Career Development, IISER Bhopal.*
- 2021 – 2022 Editor-in-chief of the student science magazine and blog, *Chrysalis, IISER Bhopal.*
- 2021 – 2022 Vice secretary of institute's *Student Development Council.*
- 2020 – 2022 Member of institute's *Debate Society.*
- 2020 – 2021 Working team member of institute's *Physics Club.*