

SAJAG KUMAR

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EDUCATION

National Institute of Science Education and Research (NISER) 2020 - 2025
Integrated M. Sc., Physical Sciences (Major), Computer Sciences (Minor)
CGPA - 9.33/10

Hope Hall Foundation School 2020
Central Board of Secondary Education, 12th Standard.
Mathematics, Physics, Chemistry, English, Physical Education, **93.4%**.

Kendriya Vidyalaya, No. 1, AF Station, Darbhanga 2018
Central Board of Secondary Education, 10th Standard.
Mathematics, Science, English, Social Science, Sanskrit, **96.8%**.

RESEARCH EXPERIENCE

The CS-WZW Correspondence August 2024 - May 2025
Advisor: *Dr. Shamik Banerjee, NISER Bhubaneswar* (Master's Thesis)

- The motivation is to understand the correspondence between $2 + 1$ dimensional Chern-Simons (CS) theory and $1 + 1$ dimensional Wess-Zumino-Witten (WZW) models.
- I have acquainted myself with $2D$ conformal field theory techniques and with the basics of gauge theories and topological quantum field theories.
- In the future, we wish to understand the implications of this correspondence for topological quantum computation.

Neural Belief Propagation Decoding of Sparse Quantum Codes May 2024 - July 2024
Advisor: *Prof. Markus Müller, RWTH Aachen* (ML4Q Internship)

- Learned about message-passing based decoders for quantum error correcting codes and got acquainted with Stim (a Python package for stabilizer circuits).
- Implemented neural belief propagation algorithm for decoding quantum error correcting codes under realistic noise models using PyTorch.
- Achieved better decoding performance than belief propagation on surface codes and recovered the threshold theorem scaling.

Prethermalization in Aperiodically Driven Classical Spins May 2023 - July 2023
Advisor: *Dr. Sayan Choudhury, HRI Prayagraj* (Visiting Student Fellowship)

- Numerically studied the non-equilibrium dynamics of aperiodically driven classical spins on a two-dimensional lattice. Established the presence of a long-lived prethermal regime and discovered a novel prethermalization time scaling.
- Established the presence of classical discrete time-crystalline non-equilibrium phases of matter called time rondeau crystals in these systems.
- *Sajag Kumar and Sayan Choudhury, Prethermalization in aperiodically driven classical spin systems, Phys. Rev. E 110, 064150.*

Geometric Phases in Optics May 2022 - July 2022
Advisor: *Dr. Ashok Mohapatra, NISER Bhubaneswar*

- Learned about geometric phases in classical optics, quantum mechanics and condensed matter physics. Studied the geometric origin of these phases using fiber bundle theory.
- Explored the possibility of experimentally demonstrating geometric phase in angular momentum space of light using Laguerre-Gaussian beams.
- Designed an undergraduate experiment to demonstrate the Pancharatnam-Berry phase using a Mach-Zehnder interferometer.

COURSE PROJECTS

DMRG Study of the Kitaev Chain

(Semester - IX)

Course: *Many-Particle Physics*, Instructor: Dr. Anamitra Mukherjee

- We calculated the **Resonant Inelastic X-Ray Scattering (RIXS)** spectrum of the Kitaev Chain, using the **density matrix renormalization group (DMRG)** algorithm.

Scrambling Dynamics in Classical and Quantum Systems

(Semester - VIII)

Course: *Computational Physics*, Instructor: Dr. Subhasish Basak, Dr. Anamitra Mukherjee

- Computed the decorrelator for classical systems, using **Monte Carlo** and **Runge-Kutta** methods for Kauffman cellular automaton and classical Heisenberg model, respectively. Used **time evolving block decimation (TEBD)** and **time dependent variational principle (TDVP)** algorithms to calculate out-of-time-ordered correlators (OTOC) for interacting quantum spin models.

Topological Quantum Error Correction

(Semester - VIII)

Course: *Quantum Information and Quantum Computation*, Instructor: Dr. Anamitra Mukherjee

- Learned the **stabiliser formalism** and braiding of anyons in the **toric code** for quantum error correction. Simulated repetition codes in **Qiskit**.

Divergence of Perturbation Theory

(Semester - VIII)

Course: *Quantum Field Theory - II*, Instructor: Dr. Yogesh K. Srivastava

- Read **Dyson's argument** for the divergence of perturbation series in quantum electrodynamics and got acquainted with modern techniques for **resummation** of divergent series.

Gamma Matrix Model for Algebraic Spin Liquid

(Semester - VII)

Course: *Advanced Solid-State Physics*, Instructor: Dr. Kush Saha

- Studied an exactly solved model whose ground state is an **algebraic spin liquid** and computed the dispersion relations. As a pre-requisite, studied **fermionisation** techniques for solving interacting spin systems.

Estimation of Electronic Band Gap Energy From Material Properties Using Machine Learning

(Semester - VI)

Course: *Machine Learning*, Instructor: Dr. Subhankar Mishra

- Used **random forest**, **gradient boosted trees**, **XGBoost** and **k-means** algorithms for various regression, classification and clustering tasks involved in a novel ensemble learning model for band gap estimation from elementary material properties.

Rosenbluth and Pruned-Enriched Rosenbluth method for Simulating Polymers on Lattices

(Semester - V)

Course: *Computational Physics Laboratory*, Instructor: Dr. Subhashis Basak

- Simulated a model of polymers as **self-avoiding random walks** on two- and three-dimensional lattices. Numerically estimated the scaling exponent for the squared end-to-end distance of polymers as a function of their length.

ACADEMIC ACHIEVEMENTS

- Selected for the **ML4Q Undergraduate Research Program** at RWTH Aachen.

2024

- Received **Visting Student Fellowship** from Harish-Chandra Research Institute. 2023
- Offered **Summer Research Fellowship** by the Indian Academy of Sciences. 2023
- **Academic excellence award** for highest SGPA (Class of 2025) in Semester - IV. 2022
- **Academic excellence award** for highest SGPA (Class of 2025, Physical Sciences) in Semesters - IV, V and VII. 2022, 2023, 2024
- **DISHA** (DAE Incentive Scheme for Holistic Science Education and Augmentation) Scholarship from Government of India. 2020 - 2025

TECHNICAL SKILLS

Programming Languages: Python, C/C++

Scientific Computation Libraries: TeNPy, Stim, QuSpin, Matplotlib, NumPy, SciPy, SymPy

Machine Learning Libraries: PyTorch, scikit-learn, TensorFlow

Markup Languages: L^AT_EX, Markdown, HTML

SUMMER SCHOOLS/WORKSHOPS/CONFERENCES

Participated and presented a poster at the **ML4Q students and postdocs summer retreat** organised by the ML4Q cluster of excellence at Siegburg, Germany. July 2024

Participated in **HSF-India HEP Software Workshop** organized at the National Institute of Science Education and Research, Bhubaneswar. December 2023

Participated in **Physics of Life 2023: The 8th Annual Monsoon School** organized by the National Center for Biological Sciences, Bengaluru, India. June 2023

Attended (online) school for masters students, **From Quantum Matter to Quantum Computers** organized by the Max Planck Institute for the Physics of Complex Systems (MPI-PKS). October 2022

Attended (online) summer school, **Curves and Surfaces: Geometry and Physical Applications** organized by the International Centre for Theoretical Sciences (ICTS). May 2022

OUTREACH AND VOLUNTEERING

Batch Representative, Vikiran (Physics Club NISER) 2022 - 2024

Organised several talks and interactive sessions on contemporary research directions in physics.

Member of Core Committee, Coding Club NISER 2022 - 2024

Responsible for designing problems for programming contests.

Head of Design, Varnapatt (Issue 01), a magazine by Vaktavya 2022

Designed the entire magazine in Adobe InDesign.

Co-Founder, Vaktavya (the debating club of NISER) 2021

Co-founded in sophomore year to foster discussions on pressing issues in science and academia.

Editor, Kshitij (Issue 04), a magazine by NISER Astronomy Club 2022

Wrote an article on gravitational wave astronomy and edited other articles in the magazine.

Head of Design, Kshitij (Issue 03), a magazine by NISER Astronomy Club 2022

Led the design team of the magazine.