KUNAL VERMA

Hostel 5, 209, IISER Mohali, Sector 81, Punjab-140306
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Interested in theoretical condensed matter physics.

EDUCATION

Indian Institute of Science Education and Research, Mohali August 2018 - Present
BS-MS Dual Degree, Physics Major
Cumulative GPA: 9.5/10.0 (till Semester 8)

Apeejay School, Sheikh Sarai, New Delhi April 2017 - March 2018
All India Senior Secondary School Examination
Percentage - 95.4% (CBSE)

Apeejay School, Sheikh Sarai, New Delhi April 2015 - March 2016
All India Secondary School Examination
CGPA - 10.0 (CBSE)

RESEARCH EXPERIENCE

5. **Semi-classical Monte Carlo simulations of $J_1 - J_2$ model** January 2023 - Present
Supervisor - Dr. Sanjeev Kumar *Master's Thesis - IISER Mohali*

- The goal of the project is to study if the singlet-dimers of the $J_1 - J_2$ model are the source of quantum fluctuations.
- Currently working on implementation of a Metropolis MCMC algorithm which includes formation and breaking of "semi-classical" singlet-dimers.

4. **Exploring topological order in $\mathbb{Z}_2$ lattice gauge theory** January 2022 - December 2022
Supervisors - Dr. Sanjeev Kumar, Prof. Vijay B. Shenoy *Master's Thesis - IISc, Bangalore*

- Studying topological order in $\mathbb{Z}_2$ lattice gauge theory by mapping it to a dual model, which turns out to be the Transverse Field Ising Model (TFIM) with the singlet constraint.
- Ising model with the singlet constraint can be simulated via a discrete-time Path Integral (quantum) Monte Carlo scheme while ensuring subsystem symmetries are preserved.
- Monte Carlo averages of physical operators can be used to study the critical properties of the model using finite-size scaling.

3. **Numerical methods to evade sign problem in lattice QCD** April 2021 - Sept 2021
Supervisor - Dr. Anosh Joseph *Summer Project - IISER Mohali*

- *Complex Langevin* and the *Lefschetz Thimble* methods as primary candidates to deal with the "sign problem" (which makes application of standard Monte Carlo methods problematic) in Lattice QCD.
  - *Complex Lagevin*: The field configuration is evolved according to a stochastic differential equation and its equilibrium configuration is chosen as the sampling configuration.
  - *Lefschetz Thimbles*: new manifolds, equivalent to the original domain of integration, are found in the complexified space, along which the imaginary part of the action is constant and, therefore, the integral is (mostly) real.

2. **Gamma-ray spectroscopy to study decay processes** December 2019
Supervisor - Prof. Rudrajyoti Palit *NIUS 16.2 Project - TIFR Mumbai*

- Introduction to methods of radiation emission and detection, radiation-matter interaction, etc.
- Methods of gamma ray detection using scintillation detectors and PMTs. Wrote a code for detection of peaks in a γ-ray spectrum.

1. **Implementing NMR Quantum State Tomography** May 2019 - July 2019
Supervisor - Prof. Kavita Dorai *Summer Project - IISER Mohali*

- Introduction to basics of *Quantum Computing* and physically realizing it using NMR.
- Explored algorithms for experimentally computing expectation values of operators, and performing Quantum State Tomography of mixed states to reconstruct the density matrix on NMR and IBM-Q.

PUBLICATIONS

1. Anosh Joseph, **Kunal Verma** (2022). *Sign Problem and Lefschetz Thimbles.* (Submitted)

TEACHING EXPERIENCE

PHY101: Mechanics	Teaching Assistant, Spring Semester 2022 - IISER Mohali.
CHM102: Quantum Chemistry	Teaching Assistant, Spring Semester 2023 - IISER Mohali.

AWARDS

INSPIRE Scholar 2018-2023	SHE (Scholarship for Higher Education).
Certificate for Academic Excellence	for a 10.0 SPI in Semester 4, 6 and 7.
S.W.A.N Imaging Challenge 2019	Winner (Team), organized by RRI Bangalore.

WORKSHOPS/CONFERENCES

From Quantum Matter to Quantum Computers, 2022	Online (MPI-PKS, Dresden).
Frustrated Metals and Insulators (Hybrid), 2022	ICTS, Bengaluru.
Shivalik HEPCATS meeting, Winter 2021	IISER Mohali.
Conference on QFTA 2019	IISER Mohali.
NIUS Physics 16.1 and 16.2 Camp	HBCSE, TIFR, Mumbai.
National Science (Vijyoshi) Camp 2018	IISER Bhopal.

TECHNICAL SKILLS

Computational Methods

Monte Carlo simulations, Path Integral (quantum) Monte Carlo , Molecular Dynamics simulations, Exact Diagonalization, Mean-Field Theory numerics, numerical integration and differentiation.

Scientific Programming languages

Fluent in Python (scipy, numpy, matplotlib), *Intermediate* knowledge of C++, *Basic* knowledge of Fortran90, Mathematica.

ADVANCED COURSEWORK

Quantum Phases of Matter and Phase Transitions *(ongoing)*, Solid State Physics, Relativistic Quantum Mechanics and Quantum Field Theory (QFT-I), Nonlinear Dynamics and Chaos, Gravitation and Cosmology, Computational Physics (Fortran), Intro to Quantum Computing: Quantum Algorithms and Qiskit, Modelling Complex Systems, Machine Learning.

REFERENCES

1. **Dr. Sanjeev Kumar**
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2. **Dr. Anosh Joseph**
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