Abhishek Raj

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RESUME SUMMARY

Experienced researcher with a strong background in theoretical physics, specializing in simulation, modeling, and analysis. Skilled in using a diverse range of programming languages and tools to simulate and analyze physical systems. Strong analytical skills, a commitment to continuous learning in emerging ideas and technologies, and the ability to collaborate effectively in team environments.

TECHNICAL SKILLS

Programming Languages : Python, Julia, Rust, Mathematica, C++, Java, Qiskit, LaTeX
Data Analytics : Pandas, Numpy, Scipy, Matplotlib, Statsmodels, Seaborn
Machine Learning : Scikit-Learn, TensorFlow, Keras, Pytorch, CUDA, NetKet
Web Development/others: Github, HTML, CSS

RESEARCH PROJECTS

Quantum Circuit Construction and Implementation of Shor's Algorithm for ECC (ECDLP) on Quantum Hardware Oct 2025 - present

- Built a hardware oriented implementation of Shor's algorithm for ECDLP over prime-field ECC.
- Circuit level point addition/doubling (no dense unitaries) and scalar multiplication, QFT period finding, and lattice post-processing.
- Validated in Qiskit 2.x and prepared for IBM backend execution.
- Developed a resource-efficient ECC toolkit for pushing the limits of quantum attacks on ECDLP on current hardware.
- Currently, we have achieved the breaking of 5-bit private key encryption with subgroup order 7.

Jamming in Kinetically Constrained Models. Aug 2024 - Apr 2025

- Developed a triangular-ladder model exhibiting both diffusive and jammed phases, with a critical density transition.
- Applied a classical–quantum mapping to reformulate the stochastic dynamics as an interacting fermion Hamiltonian.
- Performed mean-field and Hartree–Fock analysis to derive quasiparticle dispersion and effective masses, comparing predictions with exact numerical simulations.
- Identified the emergence of exponentially many jammed configurations and analyzed the entropy scaling, connecting to glassy jamming phenomena.

Non-linear Diffusion in interacting random walkers. Jun 2020 - Aug 2024

- Defined and explored lattice models of classical nonlinear diffusion in collaboration with researchers across different universities.
- Utilized Martin-Sigga-Rose (MSR) formaulation and perturbation theory for analytical solutions used it to benchmark and match with numerical solutions.
- Simulated lattice gas using vectorized Python, Julia and Rust libraries to compare performance. Leveraged multi-threading and CUDA libraries in Python and Julia to enhance simulation speeds up to 100 times.
- Confirmed a generic conjecture on late time decay of correlation functions for non-linear models and proposed corrections to it.

Phase transitions and duality in Plaquette Ising Model. Jan 2019 - May 2021

- Analyzed ground state properties of the 2D Plaquette Ising Model under transverse magnetic fields using a mean field approach and non-local spin transformations to demonstrate equivalency with the Quantum Compass model.
- Developed Python simulations to support findings using the quantum spin library based on direct methods.

- Applied deep learning based methods to approximate wavefunctions via NetKet and MPS based methods DMRG via ITENSOR to push the simulation size, comparing results across methods.
- Showed that the model has a strong first order transition and tweaked the model towards smoothening the transition.

Length scales in MBL(Many-Body Localized) phases. June - Aug 2017 ; Mar - April 2018

- Investigated distributions of localization lengths in MBL phases using interferometric probes.
- Updated the existing Python library for quantum spin systems, adding new methods and performance upgrades.
- Analyzed precession frequencies of local spins to extract statistics related to localization.
- Showed that the distribution of log couplings follows log normal distribution and proposed experimental procedure to confirm our findings.

Distinguishing integrable and non-integrable systems using quantum quenches. 2017-2018

- Led the project on differentiating integrable and non-integrable quantum systems using quench dynamics.
- Created a personal Python library to simulate quantum spin systems and analyze time evolution.
- Utilized the library to derive insights into system properties and integrability.

ML PROJECTS

RAG (Retrieval-Augmented Generation) Application

- Developed an LLM-based application for document summarization and inference.
- Leveraged the LangChain Python library to enable efficient data retrieval and content summarization.

Loan Prediction Model

- Designed a Python script for loan approval prediction.
- Compared the performance of various ML and deep learning algorithms on loan data.
- Utilized Pandas, Scikit-Learn, and Seaborn libraries for data processing and visualization.

Anomaly and Fraud detection

- Created a fraud detection model using the Isolation Forest algorithm.
- Analyzed credit card transaction data to identify anomalous patterns indicative of fraud.
- Implemented data preprocessing and visualization techniques using Python for enhanced accuracy.

EDUCATION

Doctor of Philosophy (Ph.D.), Physics — Sep, 2025
City University of New York (CUNY), New York (USA) — CGPA: 3.81/4.00
Integrated Masters of Technology (Integ. M. Tech), Engineering Physics(EP) — May, 2018
Indian Institute of Technology (BHU), Varanasi (UP, IN) — CGPA: 8.45/10.00

EMPLOYMENT

Postdoctoral Associate — Dec 2025-Present
Stony Brook University, Stony Brook, NY(USA)
Guest Researcher — Jan 2023-2025
CCQ - Flatiron Institute, Simons Foundation, New York (USA)
Adjunct Faculty — Sep-Dec 2024
Brooklyn College, CUNY.
Graduate Research Assistant — Sep 2019-June 2022
College of Staten Island, CUNY.
Internship — Mar-Apr 2018
Initiative for Theoretical Sciences, The Graduate Center, CUNY.

CERTIFICATION

Data Parallelism: How to Train Deep Learning Models on Multiple GPUs. by Nvidia
Fundamentals of Deep Learning. by Nvidia.
Numerical Linear Algebra for Financial Engineering Applications. by Baruch PreMFE Seminar.
Google Cybersecurity Certificate. by Google.

AWARDS

DSRG Grant: Doctoral Student Research Grant for travel and research during PhD
GATE Scholarship: Post Graduate Scholarship during M.Tech.

PUBLICATIONS AND CONFERENCE TALKS

Length scales in the many-body localized phase and their spectral signatures. Phys. Rev. B 100, 115136
Diffusion cascade in a model of interacting random walkers. arXiv:2412.05222
A kinetically constrained model exhibiting non-linear diffusion and jamming. J. Stat. Mech. (2025) 073208

Non-linear Diffusion processes and hydrodynamic cascades in lattice gas models.
APS March Meeting 2021, 2023