Guru Kalyan Jayasingh

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Education

Indian Institute Of Technology Bombay, India   *2017–2022 (Expected)*
Dual Degree (B.Tech + M.Tech) in Engineering Physics
Specialization: Nanoscience | GPA : 9.28/10

Key Research Experience

Electron - Phonon equilibration via Keldysh Field theory   *Feb 2020 - Present*
Supervisor: Prof. Rajdeep Sensarma, Tata Institute of Fundamental Research, Mumbai.

- We're investigating the dynamics of a coupled electron-phonon system within Keldysh formalism, where both electrons and phonons evolve in time self-consistently, as opposed to the standard paradigm of one set of constituents forming a static bath for the other.
- Studied path integral formulation of non-equilibrium Keldysh formalism.
- Used a $U(1)$ symmetric interacting model to derive self energies diagrammatically and implemented an algorithm for the numerical solution of corresponding Dyson equations.
- Wrote extensive and modular Python (& Julia) codes for evolving the coupled system and reduced high computational time (by ~ 200 times). Tested constituents by connecting them to baths and studying their equilibration characteristics starting from specific initial conditions.
- Currently working to elucidate equilibration for the coupled system in 2 & 3 dimensions. [Link]

Non-Centrosymmetric Superconductors   *Mar 2020 - Nov 2020*
Supervisor: Dr. Alexander Zyuzin, Aalto Institute, Finland.

- Extended work by Egor Babaev's group (PhysRevB.102.184517) on the effect of spin orbit coupling (SOC) on superconductivity, particularly in models of non-centrosymmetric (lacking inversion center) materials.
- Studied path integral many-body theory (particularly BCS theory), Gor'kov green's functions, and microscopic derivation of Ginzburg Landau (GL) functional.
- Investigated effects of SOC on experimentally relevant fluctuation observables like diamagnetic susceptibility, specific heat etc. near the superconducting phase transition.
- Analytically calculated and analysed the temperature & magnetic field dependence of these quantities and compared them to traditional results. [Report]

Characterizing Weyl Semimetal-Superconductor Junctions   *May 2021- Present*
Master's Thesis
Supervisor: Prof. Hridis Kumar Pal, Dept. of Physics, IIT Bombay.

- Investigating characteristics of a Superconductor(SC)-Topological insulator (TI) junction such as transition temperature (T_c), critical fields etc. and understand the role of surface states on superconducting properties.
- Studied characteristics of Superconductor-Metal junction learning quasi-classical Green's function method to treat heterostructures, and recent attempts at SC-TI junction problem.
- Found a linearized form of standard BdG formalism suitable for calculating T_c of SC-TI junctions. Currently generalizing this to SC-Weyl Semimetal junctions. [Report]

Spin polarization of half quantum vortices   *Jan 2021 - Mar 2021*
Supervisor: Dr. Alexander Zyuzin, Aalto Institute, Finland.

- Learned about the recently proposed superconducting state in doped topological insulator $Cu_x Bi_2 Se_3$ with odd parity triplet pairing and 2 component order parameters (nematic superconductivity).
- Studied fractional vortices in this model, their possible bound states and complete phase diagram based on energetics.
- Following a microscopic model, calculated spin-polarization around such vortices and discussed its experimental significance. [Report]

Talks

Bosonization and some Applications, *Condensed Matter Journal Club* *Sep 2021*
Spanning 2 sessions, the first talk focused on derivation of Bosonization identities while second talk presented a physical and heuristic view of the technique. Discussed applications by calculating conductance in impurity-ridden Luttinger wire (employing renormalization group) to illustrate new physics spawning due to reduced dimensions, interactions, and mesoscopic nature of transport. [Slides]

Fractals *Aug 2018*
We presented notion of fractional dimension, methods to characterize dimension of a fractal, and relevance of fractals for stochastic processes to the Non-linear dynamics class at the invitation of the course instructor.

A Microscope for the Fixed Point, *Maths and Physics Club, IIT Bombay* *Sep 2018*
Discussed Fixed Point theorems, some simple proofs and known applications in ODE's and numerical computation, particularly in Google's Page Rank Algorithm.

Academic Projects

Dualities in Ising model, *Advanced Statistical Mechanics* *Nov 2020*
- Studied series expansions of lattice models (specifically ising model), Kramers–Wannier duality, and $\mathbb{Z}_2$ lattice gauge theory for 3D ising model.
- Explored Elitzur's theorem and idea non-local order parameter in 3d ising gauge theory. Presented my study along with the solutions of related problems to the instructor. [Report]

Dielectric function, screening, and plasmons in graphene, *Theoretical Condensed Matter* *Nov 2020*
We studied the paper (PhysRevB.75.205418) by Hwang et al. and reproduced derivations of Polarization function, plasmon dispersion, and dielectric function in graphene. Presented our findings to the course instructor at the end. [Slides]

Spontaneous Symmetry breaking in statistical physics, *Reading Group* *Jun - Aug 2020*
Supervisor: Prof. Sumiran Pujari, IIT Bombay
Organized weekly meetups to discuss the phenomena of symmetry breaking in many-particle systems following arxiv:1909.01820. We presented our study to a faculty guide in a series of 4 talks at the end. [Notes]

Resonance Ion Spectroscopy, *Atomic and Molecular Physics* *Oct 2020*
Studied methodology of resonance ion spectroscopy and it's application in solar neutrino detection.

Gravitational simulations using tabletop BECs *Dec 2019 - Jan 2020*
Supervisor: Prof. Stefan Floerchinger, Institute for Theoretical Physics, Heidelberg.
- Explored analog gravity, which, among other things, uses quantum fluids (e.g. BEC) as model systems to mimic quantum fields in curved spacetime.
- Studied quantum field theoretic approach to condensed matter, particularly path integral analysis of weakly interacting bosons (Bogoliubov theory), and the related Gross-Pitaevskii equation describing BEC ground state.

Investigation of Fukushima-Daiichi Nuclear Disaster, *Nuclear and Particle Physics* *Oct 2020*
- Analysed publicly available datasets to formulate a diffusive model that quantifies the spread of radioactive debris post-explosion.
- We modelled spread as a function of distance, time and direction. Our analysis successfully folded in the effect of two consecutive explosions. [Slides]

Asymmetric Gravity *Jun - Jul 2019*
Supervisor: Prof. T.P. Singh, Tata Institute of Fundamental Research, Mumbai.
- Studied Non-commutative geometry (NCG) as a framework to capture quantum aspects of spacetime.
- At a coarse grained level, explored consequences of NCG by deriving new dynamical equations for gravity using an asymmetric metric tensor.

Banach Spaces and their Applications *May - Jun 2018*
Supervisor: Dr. Sutanu Roy, School of Mathematics, National Insitute of Science Education and Research.
Spent a summer studying Banach spaces, fixed point theorems and its practical use in Google's page rank algorithm, art etc. Attended a summer school on mathematics for beginning undergraduates. [Report]

Differential forms, *Reading Project* *Dec 2018*
Supervisor: Prof. Urjit Yajnik, Dept. of Physics, IIT Bombay.
Studied technique of differential Forms, its use in proving a generalised Stokes theorem, and applications in Electrodynamics.

Scholastic Achievements

2020: Selected for Aalto Science Institute (**AScI**) internship programme to pursue research on Topological matter for 12 weeks at Aalto Institute, Finland.

2019: Received **Institute Academic Prize** for the **highest GPA** in the physics department for 2018-2019.

2019: Secured **AP** grade (for extraordinary performance) in MA-214 Introduction to Numerical Analysis.

2017: Secured **99.62 percentile** in JEE-ADVANCED 2017 among 200,000 applicants.

2017: Was in the **top 400** among a total of 40,000 students, selected to appear INCHO (Indian National Chemistry Olympiad).

2017: Awarded **KVPY (Kishore Vaigyanik Protsahan Yojana) fellowship** by Department of Science and Technology, INDIA for identifying exceptional talent and promoting careers in basic sciences.

2016: Secured **National Top 1%** in NSEC (National Standard Examination in Chemistry).

Organisation and Leadership

Teaching Assistant
Courses : Advanced Statistical Mechanics (Autumn 2021), Complex Analysis (Autumn 2020) & Electromagnetism (Summer 2019)
- Conducted weekly tutorial sessions (both online and offline) for a batch of over 35 students throughout the course and helped clear conceptual doubts through personal interaction.
- Assisted instructors in conducting exams, correcting answer sheets, and selecting relevant problems for practice sets.

Manager, Maths and Physics Club, IIT Bombay   Apr 2019 - Apr 2020
- Led a team of 5 sophomores to foster enthusiasm in pure sciences, tending to a community of 400 - 500 on campus with an online presence of over 9000.
- Organized a trip to Atomic Physics and Quantum Optics Lab at IISER Pune. Lab hosts presented experiments using ultracold atoms for quantum information processing, atom interferometry, quantum chaos, etc.

Key Courses

Physics (*Theory*) - Topological Aspects of Quantum Matter*, Theoretical Condensed Matter, Advanced Statistical Mechanics, Semiconductor Physics, Quantum Devices, Introduction to Condensed Matter, Statistical Physics, Quantum Field theory (Supervised Seminar), Quantum Mechanics -I &II, Atomic & Molecular Physics, Nonlinear Dynamics.

Nanoscience (*Experiment oriented*) - Introduction to Nanoscience, Thin Film Physics, Analytical Techniques, Nanomaterials & Nanofabrication, Solid State Physics Laboratory.

Math - Complex Analysis, Calculus, Group Theory, Differential Equations - I & II, Numerical Analysis.

Programming & Miscellaneous - Computer Programming and Utilization, Data Analysis, Microprocessor lab, Digital Electronics.   *Audited at Tata Insitute of Fundamental Research, Mumbai

Technical skills

Languages: Python, JULIA, C/C++, Markdown, VHDL

Softwares: LaTeX, Mathematica, Sagemath Git, Autocad, Solidworks, Arduino

Packages: Numpy, Scipy, Numba, Pandas, Seaborn, Matplotlib, cProfile