Evening lecture (8th July)

Thirty Years of Composite Fermions And Beyond

Jainendra Jain, Penn State

The fractional quantum Hall effect is one of the most dramatic collective state of matter in nature. Many of its properties are understood in terms of emergent topological particles called composite fermions. A part of the talk will present a status report on the various manifestations and consequences of composite fermions. I will then mention two recent lines of inquiry in the field: parton theory for explaining certain delicate fractional quantum Hall States, and the density functional theory of the fractional quantum Hall effect.

Special lecture (9th July)

Unconventional Properties of Au-Ag Nanostructures

Anshu Pandey and Arindam Ghosh, IISc

This presentation will describe our observations of unconventional behavior in engineered Au-Ag nanostructures. Structurally, these comprise of ~1 nm Ag nanoclusters embedded into an Au matrix. These materials behave unconventionally and fail to exhibit metal-like behavior on several fronts. In particular, these materials show unusual transitions to a highly conductive, strongly diamagnetic state. Further, in their optical properties, a suppression of Mie-like behavior is observed along with the emergence of a broad, surprisingly non-dissipative, scattering resonance.
Abstract Title: Observation of hexatic vortex fluid in a thin superconducting film

In 1969, working on a theoretical problem out of pure mathematical curiosity, David Thouless stumbled upon a new kind of phase transition, across which physical properties show abrupt change but the free energy varies smoothly. Very soon, Michael Kosterlitz and David Thouless realised that this kind of phase transition could be ubiquitous across 2-dimensional (2D) systems. For the particular case of a 2-dimensional crystalline solid, the (Berezinski)-Kosterlitz-Thouless (BKT) theory predicts that the solid melts via a novel intermediate state, called the hexatic fluid, which possesses the orientational order of a solid but the flow properties of a fluid.

Over the years there have been several attempts to test the BKT theory in diverse 2D systems such as electrons over a liquid He surface, inert-gas monolayers adsorbed on graphite, vortices in superconducting thin films and colloidal crystals, but unambiguous identification of hexatic fluid phase has been very few. Indeed, according to the various experimental conditions one can either prove the occurrence of the melting transition at the expected value, or the existence of an orientational order when the translational one is lost, but the simultaneous observation of the two features has so far been available only in the case of some magnetic colloidal crystals. Recently, using a combination of real space imaging and transport measurements we unraveled the hexatic vortex fluid state in a thin film of the amorphous superconductor, MoGe [1]. In this talk I will discuss the properties of this hexatic vortex fluid and contrast it with the hexatic glass observed in more disordered superconductors.


Abstract Title: Signatures of Topological Superconductivity in Bulk-Insulating Topological Insulator BiSbTe$_{1.25}$Se$_{1.75}$ in Proximity with Superconducting NbSe$_2$

The combination of superconductivity and spin-momentum locking at the interface between an s-wave superconductor and a three-dimensional topological insulator (3D-TI) is predicted to generate exotic p-wave topological superconducting phases that can host Majorana Fermions. However, large bulk conductivities of previously investigated 3D-TI samples and Fermi level mismatches between 3D bulk superconductors and 2D topological surface states have thwarted significant progress. Here, we employ bulk-insulating topological insulators in proximity with two-dimensional superconductor NbSe2assembled via van der Waals epitaxy. At first, a bulk insulating topological insulator
BiSbTe1.25Se1.75 is developed which has shown diverse exotic properties. Secondly, high quality NbSe2 were grown. Then, by suitable means, the Bose metal phase in NbSe2 is fully quenched restoring a perfectly superconducting state. These two systems were combined in a highly inert environment through van der Waals epitaxy to realize the exotic topological superconductor. Experimentally measured differential conductance yields unusual features including a double-gap spectrum, an intrinsic asymmetry that vanishes with small in-plane magnetic fields, and differential conductance ripples at biases significantly larger than the superconducting gap. We explain our results on the basis of proximity-induced superconductivity of topological surface states, while also considering possibilities of topologically trivial superconductivity arising from Rashba-type surface states. Our work demonstrates the possibility of obtaining p-wave superconductors by proximity effects on bulk-insulating TIs.

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**Abstract Title:** Stability of multielectron bubbles in liquid helium

Neha Yadav, Yunhu Huang, Emil Joseph, Vaisakh Vadakkumbatt, Ambarish Ghosh

Multielectron bubbles (MEBs) are cavities in liquid helium containing more than one electron. These objects provide a rich platform to study the properties of a two-dimensional electron system over a wide range of densities, as well as to investigate the effects of curvature. Although they have been predicted to show many interesting properties, the experimental progress has been relatively limited with most studies confined to their observation and measurement of charge. In a recent development, we have been able to trap the MEBs in a Paul trap and subsequently measure their properties in a non-destructive manner. Our studies reveal the bubbles to be stable and long-lived under the presence of vapor inside the bubbles, which allowed us to study the shape and dynamics of these objects over an extended duration. A question that naturally arises is what happens to the bubbles as the vapor condenses, and whether the MEBs are stable against shape perturbations. From the experiments carried out across the Lambda point, we conclude the MEBs to spontaneously break into smaller objects till they cannot be imaged any more. The final stable configuration appears to be bubbles containing very small (6-12) number of electrons, in accordance with recent theoretical predictions.
Abstract Title: The Langevin approach to correlated quantum systems

While the thermodynamic properties of correlated systems can be accessed via tools like quantum Monte Carlo the dynamical properties associated with collective modes are much harder to access. In such cases a stochastic "equation of motion" approach, motivated by the real time Keldysh framework, is more fruitful in studying the finite temperature dynamics. I hope to discuss two cases (i) the equilibrium lattice dynamics in a strongly coupled electron-phonon system across its charge ordering thermal transition, and (ii) the non equilibrium response of a Mott insulator to a strong voltage bias.

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Abstract Title: Kardar Parisi Zhang (KPZ) scaling in non-integrable and integrable classical spin chains

We will present results on equilibrium spatio-temporal correlations in classical non-integrable and integrable spin chains. For the non-integrable case, we consider the classical XXZ model (Lattice Landau Lifshitz model) and show regimes where we find KPZ scaling [1]. We explain it using the framework of nonlinear fluctuating hydrodynamics (NFH). To our surprise, we find that a classical integrable spin chain, namely, the Faddeev-Takhtajan model [2] also has regimes in which it displays KPZ behaviour. Our findings are along the lines of what was recently found in quantum integrable spin chains thereby providing strong evidence for a classical-quantum correspondence.


Name: Sumilan Banerjee
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Abstract Title: Quench, thermalization and residual entropy across a non-Fermi liquid to Fermi liquid transition

In recent years, a zero-dimensional solvable model of interacting fermions, namely Sachdve-Ye-Kitaev (SYK) model, has emerged as a new paradigm to describe non-Fermi liquid metals as well as thermalization and many-body quantum chaos in interacting systems. I will discuss thermalization, after sudden and slow quenches, in a related model having a quantum phase transition from a Sachdev-Ye-Kitaev (SYK) non-Fermi liquid (NFL) to a Fermi liquid (FL). The model has SYK fermions coupled to non-interacting lead fermions and can be realized in a graphene flake connected to external leads. The study of quench in this model gives an explicit demonstration of the intriguing
contrasts between the out-of-equilibrium dynamics of a NFL and a FL in terms of their thermalization and approach to adiabaticity.

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Abstract Title: Novel Magnetism in Low-Dimensional Quantum Spin Systems

Triangular, square, Kagome, and honeycomb spin lattices are of special importance in low dimensional magnetism. In such geometries, frustrated quantum magnetic systems provide a rich playground for interplay of competing exchange interactions and quantum fluctuations, and are at the forefront to explore unconventional phases of condensed matter. It is important to understand the physics of such spin systems. Neutron scattering is known to be an excellent microscopic probe to reveal the nature of magnetic ground states in a large variety of such spin systems with reduced dimensions involving quantum fluctuations.

I will present the recent experimental results of neutron diffraction elucidating the microscopic nature of magnetic correlations in some of these spin systems. The experimental results will be compared with the available theoretical results revealing the physics of such novel spin systems with regard to their physical properties in reduced dimensions involving quantum fluctuations.

Abstract Title: Excitonic or Ground state Magnetism? A debate in spin-orbit coupled Iridates

Investigation of elementary excitations has advanced our understanding of many-body physics governing most physical properties of matter. Recently spin-orbit excitons have drawn much attention, whose condensates near phase transitions exhibit exotic physical phenomenon [Nat. Phys. 13, 633 (2017)]. These critical transition points resulting from competing spin-orbit coupling (SOC), local crystalline symmetry and exchange interactions, are not obvious in Iridium based materials, where SOC prevails in general. Here, we present results of resonant inelastic x-ray scattering (RIXS) on a spin-orbital liquid Ba$_2$Znlr$_2$O$_9$ and three other 6H-hexagonal perovskite iridates which show magnetism, contrary to non-magnetic singlet $J=0$ ground state expected due to strong SOC. Our results show that substantial hopping between closely placed Ir$^{3+}$ ions within Ir$_2$O$_9$ dimers in these 6H-iridates, modifies spin-orbit coupled states and reduces spin-orbit excitation energies. Here, we are forced to use at least a two-site model, to match the excitation spectrum going in line with the strong intra-dimer hopping. Apart from SOC, low energy physics of iridates is thus critically dependent on hopping, and may not be ignored even for systems having moderate hopping, where the excitation spectra can be explained using an atomic model. SOC which is generally found to be 0.4-0.5 eV in iridates, is scaled in effect down to ~0.26 eV for the 6H-systems, sustaining the hope to achieve quantum criticality by tuning Ir-Ir separation.

Abstract Titles: Inversion and quantum oscillations in Kondo insulators

Recent observations of magnetic quantum oscillations [de Haas-van Alphen (dHvA) effect] in a Kondo insulator (SmB6) challenge the conventional view that the dHvA oscillations can occur only in metals. We study this problem by investigating the basic models of Kondo insulators for their orbital response to uniform magnetic field. With the help of a self-consistent charge dynamics, in a novel representation for electrons, we discover that the gapped charge quasiparticles undergo inversion upon decreasing the Kondo coupling, and due to this inversion, the dHvA oscillations occur as a bulk phenomenon in the Kondo insulating state [1,2].

References:
Abstract Title: Possible emergence of coherent Kondo lattice in Pyrochlore Pr$_2$Ir$_2$O$_7$

Pyrochlore Iridates display interesting interplay of geometric frustration, spin-orbit coupling and Coulomb correlation potentially leading to a wide variety of novel phases such as spin-orbit coupled Mott insulator, topological semimetal, axion insulator, chiral spin liquid, etc. Among the Pyrochlore Iridates, Pr2Ir2O7 is known to be a metallic spin liquid in bulk form. The low temperature resistivity in the bulk shows a shallow minimum which is attributed to the scattering off Kondo singlet formed by conduction electrons in Ir 5d orbitals interacting with local moment due to Pr 4f electrons. However it is not clear whether a straightforward application of the Kondo mechanism is at all feasible as the magnetic susceptibility diverges well below Kondo temperature. In this talk we shall discuss the transport properties of single crystalline nanowire based on Pr2Ir2O7 and the possible emergence of coherent Kondo lattice in the same vis-à-vis the bulk system.

Abstract Title: T=0 RG Phase diagram of the Kagome XXZ quantum antiferromagnet for the 1/3--magnetisation plateaux

The study of quantum spin liquids on geometrically frustrated lattice has a long history. In recent times, the search for non---trivial ground states at finite magnetic field, appearing in the form of plateaux in the magnetisation versus field plot, has also picked up pace. I will present our recent work on an investigation of the XXZ quantum antiferromagnet on the two---dimensional kagome lattice at $1/3$ magnetisation per site [1]. We begin by employing a Jordan---Wigner transformation to map the spin problem into one of spinless fermions (spinons) in the presence of a statistical gauge field, and with nearest--- neighbor interactions. Then, with the help of a non----perturbative zero---temperature renormalization group (RG) technique, we analyze the role of inter--- spinon interactions in shaping the phases around this plateau in the entire XXZ model. The RG phase diagram obtained contains three spin liquid phases whose position is determined as a function of the exchange anisotropy and the energy scale for fluctuations arising from spinon scattering. Two of these spins liquids are topologically ordered states of matter with gapped, degenerate states on the torus. The gap for one of these phases corresponds to the one---spinon band gap of the Azbel---Hofstadter spectrum for the XY part of the Hamiltonian, while the other arises from two---spinon interactions. The Heisenberg point of this problem is found to lie within the interaction gapped spin liquid phase, in broad agreement with a recent experimental finding. The third phase is an algebraic spin liquid with a gapless Dirac spectrum for spinon excitations, and possess properties that show departures from the Fermi liquid paradigm. The three phase boundaries correspond to critical theories, and meet at a SU(2)---symmetric multicritical point. I will also discuss the relevance of our findings to various recent experiments, as well as results obtained from other theoretical analyses.

**Abstract Title: Low Temperature Magnetic properties of Frustrated Spin-1/2 systems**

We study the quantum phase diagram and low temperature magnetic properties of a frustrated spin-1/2 one dimensional systems. In this talk we show that the frustration in the system can induce various kind exotic phases. It is well know that study of magnetic propeties of a frustrated system at low temperature is not reliable. In this presentation we will also try to show that density matrix renormalization group method is a reliable numerical method to calculate the low temperature properties of these systems.

**Abstract Title: Order by singularity**

We conjecture that any cluster of quantum spins, in the low energy limit, reduces to the problem of a single particle moving in the space all classical ground states. We justify this equivalence using the language of path-integrals. We explicitly demonstrate it in a class of clusters with XY couplings. Geometric phases emerge in our description; they must be carefully incorporated to see the equivalence. We discuss a particularly interesting case with spins on a tetrahedral cluster. The classical ground state space is a non-manifold, self-intersecting at line-singularities. We study particle dynamics on this space using a tight binding approach. Remarkably, the entire low energy spectrum consists of bound states that are localized around the singular lines. For the spin cluster, this manifests as a preference for collinear ground states over other classical ground states. This 'order by singularity' arises from the topology of the space, rather than from thermal or quantum fluctuations. Unlike order-by-disorder, this effect persists even in the classical limit.

**Abstract Title: Quantum Transport models for nanowire hybrid systems**

Semiconductor nanowire-superconductor hybrid systems provide a promising platform for hosting unpaired Majorana fermions and thus realizing fault-tolerant topological qubits. In this study, we employ the Non-Equilibrium Green’s Function (NEG) Formalism to model quantum transport in normal (N)-superconductor (S) junctions. We analyze Josephson junctions based on semiconductor nanowires and derive the Andreev bound state spectrum and current-phase relations. Recently,[1], and [2] have reported oscillations in the critical supercurrent with an axial magnetic field. Our simulations indicate that this phenomenon arises from the interference of orbital angular momentum modes [3,4] of the cylindrical nanowire. We also add disorder and study its effect on the critical current oscillations, with an aim to gain a thoroughgoing understanding of the experiments.
Superconductivity is known in several metals, alloys and Copper-oxide based high-Tc compounds. Metals have electron densities $\sim 10^{23} \text{cm}^{-3}$ and the high T$_{C}$ oxides nearly 100 times lower than that. These are far too high to make them gate tunable by any practical combination of gate voltages and insulator. In general it is indeed correct that if the carrier density is low, the density of states at Fermi level would also be low. A casual look at the basic BCS relation connecting T$_{C}$ and the density of states at Fermi level would suggest that low carrier density would make superconducting state less likely. Semiconductors have much lower carrier density than metals and indeed superconductivity is quite rare in semiconductors. While some semiconductors like Germanium Telluride, heavily boron-doped diamond etc are known to superconducting, these has to be doped to very high degeneracy and the superconducting state is weak. In this context the occurrence of a robust superconducting state in Indium Nitride, with carrier densities $\sim 10^{18} \text{cm}^{-3}$ has evoked a lot of interest. In this talk I would describe our recent efforts to understand the nature of the superconducting state in a III-V semiconductor – Indium Nitride. The unexpected occurrence of superconductivity in InN with typical T$_{C} \sim 3$ Kelvin, was reported about twenty years back but there has been certain uncertainties about what makes the material superconducting. We have recently carried out angle dependent critical field measurements to show that the superconducting state in InN is most likely confined to a surface layer and possibly hosted by the surface states that pin the Fermi level of InN above the conduction band. Carrier densities in the 1017- 1018 cm$^{-3}$ range can be achieved in InN that brings in on the verge of potential “gate control” by conventional metal-dielectric gates and certainly within the range of electrolytic gates. I will discuss recent experimental results from our group about this aspect.

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Abstract Title: Layered magnetic topological semimetals and their unusual interlayer quantum transport

Recent discoveries of three dimensional topological semimetals have generated immense interests since they represent new topological states of quantum matters. In this talk, I will first give a brief introduction to this emerging direction and then present our recent studies on topological semimetals [1-4], which are focused on Dirac/Weyl fermions generated by square lattices in layered compounds. I will first report on our discoveries of new magnetic Dirac semimetals (Sr/Ba)$_x$Mn$_{1-x}$Sb$_2$ [1,2]. In Sr$_{1.9}$Mn$_{1.5}$Sb$_2$, Dirac fermions are found to coexist with ferromagnetism, offering a rare
opportunity to investigate the interplay between relativistic fermions and spontaneous time reversal symmetry breaking [1]. For Ba$_{1-x}$Mn$_x$Sb$_2$, we observed half-integer bulk quantum Hall effect and 2D chiral surface states. Furthermore, we have also studied the unusual interlayer quantum transport resulting from the zeroth Landau level (LL) mode in type-II Weyl semimetal YbMnBi$_2$ [3]. The interlayer magneto resistivity and Hall conductivity of this material were found to exhibit surprising angular dependences under high fields, which can be well fitted by a model which considers the interlayer quantum tunneling transport of the zeroth LL’s Weyl fermions. Our results shed light on the unusual role of zeroth LL mode in transport.

References:

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Abstract Title: Quantum Anomalous Hall Effect in the Magnetic Topological Insulator Thin Films

The quantum anomalous Hall (QAH) effect can be considered as the quantum Hall (QH) effect without an external magnetic field, which can be realized by time-reversal symmetry breaking in a topologically non-trivial system [1, 2]. A QAH system carries spin-polarized dissipationless chiral edge transport channels without the need for external energy input, hence may have a huge impact on future electronic and spintronic device applications for ultralow-power consumption. The many decades quest for the experimental realization of QAH phenomenon became a possibility in 2006 with the discovery of topological insulators (TIs). In 2013, the QAH effect was observed in thin films of Cr-doped TI for the first time [3]. Two years later in a near-ideal system, V-doped TI, contrary to the negative prediction from first principle calculations [2], a high-precision QAH quantization with more robust magnetization and a perfectly dissipationless chiral current flow was demonstrated [4]. In this talk, I will introduce the route to the experimental observation of the QAH effect in aforementioned two systems [3, 4], and talk about our recent progress on QAH sandwich heterostructures from the axion insulator physics and the topological Hall effect [5,6].
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Abstract Title: Magneto-thermal chiral anomaly and transport in Weyl semimetal

Weyl semimetals host Berry curvature monopoles of opposite chirality. In presence of parallel electric and magnetic fields, the chiral symmetry breaks down leading to magneto-electrical chiral anomaly: charge pumping from the positive chirality monopole to the negative chirality monopole. In a crystalline system, this charge pumping is generally stabilized by inter-node scattering, leading to different chemical potential in the two Weyl nodes of opposite chirality and has been demonstrated in several recent transport and optical experiments. We predict a thermal analogue of this phenomena, a magneto-thermal chiral anomaly in which the application of parallel magnetic filed and temperature gradient lead to change pumping and chemical potential imbalance between the two Weyl nodes of opposite chirality. This magneto-thermal chiral anomaly will manifest itself in the magneto-thermal transport including the planar Ettinghausen effect and planar thermal Hall effects.

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Abstract Title: Quantum many-body scars in periodically driven tilted Bose-Hubbard model

We study the the dynamics of a periodically driven tilted Bose-Hubbard model starting from a $Z_2$ symmetry broken state. We find long-time oscillations in the density-density correlation function of the bosons and relate them to the presence of scar-like states in the eigen spectrum of its Floquet Hamiltonian. The nature of these states depends on the drive frequency $\Omega_0$. At high drive frequencies, these states are identical to their equilibrium counterparts. However, for lower drive frequencies, their nature deviates significantly from equilibrium scar states and leads to complex oscillation patterns in the correlation functions. We show that such patterns can be semi-analytically understood using a Magnus expansion at moderate drive frequencies. At very low frequencies where the Magnus expansion fails, we find that the dynamics of the correlation functions are governed by a set of states which leads to complex long-time oscillations usually attributed to the presence of scar-like states. However, unlike standard scars, these states satisfy volume law entanglement and are not natural outliers outside the band of ETH obeying states in the Floquet spectrum. We discuss the properties of these states which have no obvious equilibrium analog and chart out experiments which can test our theory.
Abstract Title: Quantum speed limit and unbounded temporal correlation in open quantum systems

Leggett–Garg types of inequalities define bounds on certain temporal correlations constructed out of joint probability of outcomes of successive quantum measurements originally proposed by Leggett and Garg. These inequalities quantify the quantumness of a system under study. For a two level system, Leggett–Garg correlation is bounded by 1.5 which is popularly referred to as the Lüders bound. In this talk, I will show that a two level system coupled to a bath can not only exceed the Lüders bound but can also approach values which are asymptotically close to the algebraic bound of Leggett–Garg inequalities when the quantum measurement acting on the system is chosen from an optimal set. This is rather counterintuitive as it indicates strong enhancement in quantumness under the presence of a bath which does induce decoherence in the system. I will demonstrate that the extremal violation of Leggett–Garg inequalities is directly related to boosted quantum speed limit due to the presence of the bath.

Abstract Title: Memory of Initial States in Quantum Dynamics: Density Imbalance in Disordered Interacting Systems

We develop a new field theoretic formalism to describe non-equilibrium dynamics of quantum many body systems starting from arbitrary initial conditions. We use this new technique to study the dynamics of one and two dimensional disordered lattice bosons/fermions initialized to a Fock state with a pattern of 1 and 0 particles on A and B sites. For non-interacting systems we establish a universal relation between the long time density imbalance between A and B site, \( I(\infty) \), the localization length \( \xi \), and the geometry of the initial pattern. For alternating initial pattern of 1 and 0 particles in 1 dimension, \( I(\infty) = \tanh[a/\xi] \), where \( a \) is the lattice spacing. For systems with mobility edge, we find analytic relations between \( I(\infty) \), the effective localization length \( \xi_{\text{eff}} \) and the fraction of localized states \( f_{\text{L}} \). The imbalance as a function of disorder shows non-analytic behaviour when the mobility edge passes through a band edge. For interacting bosonic systems, we show that dissipative processes lead to a decay of the memory of initial conditions. However, the excitations created in the process act as a bath, whose noise correlators retain information of the initial pattern. This sustains a finite imbalance at long times in strongly disordered interacting systems.

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Abstract Title: THz Photodetector using sideband-modulated transport through surface states of a 3D Topological Insulator

Puja Mondal, Sankalpa Ghosh and Manish Sharma

The transport properties of the surface charge carriers of a three dimensional topological insulator under a terahertz (THz) field along with a resonant double barrier structure is theoretically analyzed within the framework of Floquet theory to explore the possibility of using such a device for photo detection purpose. We show that due to the contribution of elastic and inelastic scattering processes in the resulting transmission side-bands are formed in the conductance spectrum. This side band formation is similar to the side-bands formation in cavity transmission spectra in an optical cavity and this information can be used to detect the frequency of an unknown THz radiation. The dependence of the conductance on the bias voltage, the effect of THz radiation on resonances and the influence of zero energy points on the transmission spectrum are also discussed.

Name: Awadhesh Narayan  
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Abstract Title: A Tale of Tunable Dirac Points

Going beyond the flatland of graphene, Dirac and Weyl semimetals with gapless dispersions in three dimensions have generated widespread recent interest [1], due to their intriguing properties [2]. In this talk, I will describe strategies to engineer the creation, motion and annihilation of such Dirac points using alloying [3] and light [4]. Next, I will show how line node semimetals – systems with a continuous line rather than isolated points of band crossings – under light illumination can be used to create Dirac-Weyl points on demand [5]. I will end with the implications of such changes in Fermi surface topology in transport signatures, in particular a light-controlled Hall conductance.

Name: Priya Mahadevan  
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Abstract Title: Unexpected symmetries in twisted bilayer MoSe₂

Spin-orbit interactions lead to a large spin-splitting of the valence band maximum at K in MoSe₂ monolayers. However, on stacking a second layer of MoSe₂ in the same manner (2H) as found in the bulk, one finds that there is no net spin splitting. This has been attributed to the presence of inversion symmetry. As exploiting the spin splitting at the K valleys allows us to increase the functionality, an obvious route to making the bilayers useful for exploring the coupled spin and valley physics is through breaking inversion symmetry. We examined this by rotating the top layer of the bilayer by an angle θ with respect to the lower layer. The choice of angles was restricted to those for which one had reasonable sized supercells and were otherwise arbitrary. Surprisingly, we found several instances where the spin splitting vanished, though there was no breaking of inversion symmetry. An unusual mechanism behind this is identified. Additionally we found that while the spin splitting existed for θ, it vanished for 60-θ. This unusual behavior, we find, is a consequence of the symmetry of the hexagonal Brillouin zone.

*This is work done in collaboration with Poonam Kumari and Joydeep Chatterjee.

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Abstract Title: Physics of 2D Heterostructures: Doping, exciton, transport and Fermi surface Nesting

Two-dimensional heterostructures (HS), assembled through either van der Waals or chemical bonding or by both, furnish a playground to nurture various exotic material aspects and novel phenomena. Basic understanding of physics and chemistry of interfaces of 2D systems are a primary requirement to analyze the origin of all these phenomena. In the present talk, we will present a glimpse of some such HS, where combinatorial control can generate interesting electronic properties. In semiconductor-semiconductor HS, we will present systems like MoSe₂/GO, MoS₂/TiO₂ and MoS₂/ReS₂, where interlayer coupling and perfect surface termination can intricately control the doping dynamics and thus manipulates the excitonic behavior and transport properties. For metal-metal interfaces, we will discuss how engineered interfaces of some common FCC metals are able to produce nested Fermi-surface, near Fermi-energy flat bands and thereby can predict presence of charge-density waves (CDW) for such nanostructured interfaces. Such systems are highly optically non-linear at their epsilon-near-zero energy regions. At the end, we will demonstrate that at the interface of Weyl semi-metal and some FCC metals, hexagonal symmetry plays an important role to stabilize hole-doped antiferromagnetic ground state. Reconstruction of Fermi-surface and presence of incommensurate nesting also predict presence of CDWhin these systems. The metal-metal and metal-semimetal interfaces will also be presented in details by the student in his presentation.
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Abstract Title: Substrate Induced Huge Magnetic Anisotropy in Cobalt-C-Vacancy Complexes In Graphene Sheet Supported on Ni(111) Surface

Niharika Joshi and Prasenjit Ghosh

Exploring giant magnetic anisotropy in magnetic nanostructures is of immense importance for information storage. Large magnetic anisotropy energy (MAE) requires large spin-orbit coupling energy, large orbital moment and strong ligand field. Among these three factors, modifying ligand field is a feasible way for tuning MAE. This is because, while spin-orbit coupling, depends on the choice of atomic species and the orbital moment depends inversely on the strength of the ligand field.

Towards this end, we have performed ab initio density functional theory calculations to investigate the magnetic properties of the Co-adatom-C-vacancy complexesin freestanding and Ni(111) surface-supported graphene sheet for high density magnetic storage device applications. The vacancies in graphene facilitate a well-ordered arrangement of the TM adatoms unlike on pristine graphene [1, 2] and TM surfaces [3] where the TM adatoms can spatially switch their positions. However, the strong interaction between Co atom and vacancy in the graphene sheet quenches the large magnetization of the Co atom almost by an order of magnitude and also results in a weak magnetic anisotropy energy (MAE) [4-6]. In an effort to enhance the MAE we tuned the ligand field by replacing the C atoms surrounding the vacancies with N and B atoms in the freestanding graphene. Amongst the different decorated C vacancies, B-decorated single vacancy complex structure shows largest MAE for Co adatom (about 1.61 meV with the easy axis perpendicular to the graphene sheet). However, we find that the MAE of Co adatom adsorbed at the vacancies in graphene sheet is largely enhanced when the graphene sheet is supported on Ni(111) surface irrespective of whether the vacancies are clean or decorated with N or B atoms. The MAE for different single and double vacancy complexes, undecorated and decorated with N and B, in the graphene sheet supported on Ni(111) surface range from 39-45 meV with easy axis perpendicular to the graphene surface. By analysing the spin-orbit coupling Hamiltonian within second order perturbation theory [7] we attribute the huge enhancement in MAE to the interaction of Co-vacancy complex in graphene sheet with its Ni(111) substrate.

References:
Abstract Title: ABO$_3$ perovskites with Active A-sites

We consider ABO$_3$ perovskites with active A site like Bi or Pb, which has extended 6s orbitals. Using ab initio electronic structure and slave rotor theory calculations, we demonstrate [1] that hybridization-switching induced Mott transition happens in a class of these compounds, namely BiNiO$_3$ and PbCrO$_3$. We show that these systems exhibit a breathing phonon driven A-site to oxygen hybridization-wave instability which conspires with strong correlations on the B-site transition metal ion (Ni or Cr) to induce a Mott insulator. In contrast to perovskites with passive A-site cations, these Mott insulators with active A-site orbitals are shown to undergo a undergoing pressure induced insulator to metal transition accompanied by a colossal volume collapse due to ligand hybridization switching. Finally, we contrast this situation with that of BiFeO$_3$ or PbVO$_3$ which shows polar distortion rather than breathing distortion of A-O sublattice. We discuss the microscopic origin of this contrast.[2]

Work carried out in collaboration with Atanu Paul, Anamitra Mukherjee, Indra Dasgupta, Arun Paramekanti


Abstract Title: Disorder in phononic systems: A cluster Green's function approach

The effect of disorder on lattice vibrational modes has been a topic of interest for several decades. In this talk, I will discuss a Green's function based approach, namely, the dynamical cluster approximation, that has been employed to investigate phonons in mass and force-constant disordered systems. Detailed benchmarks with previous exact calculations are used to validate the method in a wide parameter space. An extension of the method, namely, the typical medium DCA (TMDCA), is used to study Anderson localization of phonons in three dimensions. Several physics insights will be discussed in the talk. The overall objective of the talk will be to establish a new computational approach, which recovers the thermodynamic limit, and is versatile and computationally inexpensive, for investigating lattice vibrations in disordered lattice systems.
Abstract Title: A correlated approach to the normal state and dimensional crossover in doped strontium

Layered Sr$_2$RuO$_4$ has long attracted intense attention owing to the expectation that superconductivity in it is an analogue of superfluid $^3$He, with a spin-triplet, odd-parity chiral order parameter. Such a state would support half-quantum vortices and topologically protected chiral Majorana modes at the sample edges or on domain walls. A range of data however also attests to the presence of line nodes in the SC gap function. Moreover, presence of sizable spin-orbit coupling (SOC) and multi-orbital character of the system dictate that the multi-band pair function reflects spin-orbital entanglement. Since the superconductivity here is an instability of its highly correlated Fermi liquid (FL) state, resolution of its pairing symmetry requires a microscopic description of the normal state itself. Over the years, extensive experimental studies reveal (i) a T-dependent incoherence-coherence (IC-C) crossover from an incoherent high-T metal to a strongly correlated FL metal below TFL~ 20–25 K. (ii) Very recent correlated first-principles calculations show the complex interplay between one-electron band structure, local multi-band interactions and SOC. Moreover, the IC-C crossover has been interpreted in terms of Hund’s metal physics, where sizable influence of Hund coupling ($J_H$) drastically reduces the lattice-FL crossover scale. The single- and two-particle responses at three different points ($x=2.0$, 0.5, 0.0) in the iso-electronic series Ca$_{2-x}$Sr$_x$RuO$_4$ show anomalous cross-over from Hund’s metal ($x=2.0$) to a Mott insulator ($x=0$) where a structural distortion is likely to be responsible. We show that there is a quantum critical end point (QCEP) of second-order structural transition at $x=0.5$ which is associated with an effective 3D cross-over from the quasi-2D structures of $x=2.0$ and $x=0.0$ end-members. Finally we draw an electronic and magnetic phase diagram in T-x plane with these novel inputs, with a fan like region starting from the QCEP at $x=0.5$.


Abstract Title: Multipartite entanglement at dynamical quantum phase transitions with non-uniformly spaced criticalities

We report dynamical quantum phase transition portrait in the alternating field transverse XY spin chain with Dzyaloshinskii-Moriya interaction by investigating singularities in the Loschmidt echo and the corresponding rate function after a sudden quench of system parameters. Unlike the Ising model, the analysis of Loschmidt echo, analytically, yields non-uniformly spaced transition times in this model. Comparative study between the equilibrium and the dynamical quantum phase transitions in this case reveals that there are quenches where one occurs without the other and the regimes where they co-exist. However, such transitions happen only when quenching is performed across at least a single gapless or critical line. Contrary to equilibrium phase transitions, bipartite entanglement measures do not turn out to be useful for the detection while multipartite
entanglement emerges as a good identifier of this transition when the quench is done from a disordered phase of this model.

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Abstract Title: Star-topology Quantum Registers  
A quantum bit (qubit) can store the basic unit of quantum information. A network of qubits forms a quantum register. Having each qubit directly interacting with all other qubits would be ideal, but not practical. Therefore, the topology of the network plays an important role in determining the efficiency of the register in executing various tasks. In this talk, star-topology registers and their extensions will be discussed. The star-topology provides the most efficient pathway for preparing multi-qubit entanglement. Various applications of star-registers and their experimental implementations using nuclear magnetic resonance will be discussed.

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Abstract Title: Building a highly connected quantum processor using superconducting circuits  
Quantum computers bring in extraordinary capabilities at solving certain problems by taking classically inaccessible paths. A practical quantum computer will need a large number of qubits with good coherence and high fidelity control and measurement. In addition, a highly connected qubit network will also enable efficient implementation of quantum algorithms by minimizing the number of gates needed. This is particularly important in the current era of small-scale quantum processors which are prone to errors due to finite coherence time. In this talk, I will highlight our efforts in developing a highly connected qubit network using superconducting circuits. In particular, I will discuss a novel three-qubit circuit with all-to-all coupling [1,2] and a new coupling architecture using resonant cavities for enhanced connectivity. I will conclude by discussing the possible extensions of these ideas for scaling up the size of the quantum processor.

Abstract Title: A three-dimensional waveguide cavity-based platform for quantum optomechanical experiments

Superconducting devices have emerged as one of the leading platforms for implementing quantum technologies. Cavity-optomechanical systems implemented with superconducting circuit elements have shown an exquisite control over the quantum states of massive-mechanical resonators. In this talk, I will initial results from an optomechanical platform based on a 3-dimensional waveguide cavity. In this system, we demonstrate a participation ratio of 43%, achieved by coupling a mechanical resonator to the modified electromagnetic mode. The optomechanical coupling is characterized by performing measurements in optomechanically-induced absorption limit. The low-impedance environment of our design offers the flexibility to incorporate a DC bias across the mechanical resonator, often a desired feature in tunable optomechanical devices. A pseudo-lumped nature of the electromagnetic mode in such a device, paves the way towards developing hybrid system with superconducting qubits, which has the potential to achieve control of massive oscillators down to a single-phonon, and to realize storage of the quantum information in mechanical vibrations.

Abstract Title: Upper bounds on the superconducting transition temperature: Applications to twisted-bilayer graphene and ultra-cold Fermi gases

Understanding the material parameters that control the superconducting transition temperature Tc is a problem of fundamental importance. We use sum rules to derive a rigorous upper bound on the superfluid phase stiffness Ds valid in any dimension. This in turn leads to an upper bound on Tc in two dimensional (2D) systems, which holds irrespective of mechanism, strength of pairing interaction, or order-parameter symmetry. While this bound is of general validity, it is particularly useful and leads to stringent constraints for the strongly correlated regime of low density and narrow-band systems, where conventional the BCS-Eliashberg approach fails. For a simple parabolic band, we find that in 2D Tc can never exceed (Fermi Energy)/8, a bound which is close to being saturated in ultracold Fermi gases in the strongly interacting regime of the BCS-BEC crossover. Applying our multi-band bound to magic-angle twisted bilayer graphene we find that the available electronic structure results already constrain the maximum possible Tc to be close to the experimentally observed value. Finally, I will discuss the theoretical challenges in deriving rigorous upper bounds on Tc in three dimensions (3D) and compare with experiments.
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Abstract Title: Unconventional mixed phase in a conventional superconductor with type II Dirac bands

PdTe$_2$ is a topological type II Dirac semimetal which also shows superconductivity below 1.7 K. Naturally it was speculated that the superconducting phase could actually be topological in nature. We have shown that despite the presence of topologically non-trivial bands, PdTe$_2$ is a conventional superconductor where superconductivity is fully gapped and no mid-gap states are present. The magnetic properties of the system turned out to be more interesting because the surface displayed certain domains where superconductivity was “type I”-like and in other domains it was “type II”-like. We performed scanning tunneling spectroscopy in both normal and superconducting states and found a correlation between an electronic inhomogeneity that was seen in the normal state with the mixed phase that we observed in the superconducting state. We surmised that the normal state electronic inhomogeneity caused a distribution of coherence length on the surface leading to the mixed phase. In order to prove this, we disordered the surface by artificially adding copper atoms by bulk intercalation and by heavy ion irradiation and found that the superconducting phase becomes homogeneously type II when disordered, as expected.

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Abstract Title: Superconductivity in non-centro symmetric Re6Zr probed by Point contact Andreev reflection spectroscopy

Re6Zr, is a non-centrosymmetric superconductor with a superconducting transition temperature (Tc) of 6.78 K and has a simple –Mn cubic crystal structure. Recent muon spectroscopic measurements on this system has suggested that its superconducting state breaks time reversal symmetry implying a mixture of spin singlet-spin triplet states leading to a complex order parameter in this system. We report point contact Andreev Reflection (PCAR) measurements on a single crystal of Re6Zr where at the lowest temperature of T = 1.6 K, we observe multiple gap features in the PCAR spectra appearing at voltages 1.0±0.1 mV, 0.75±0.05mV and 0.45±0.1mV. Out of these, the bulk gap (2 = 1.95kBTc = 1.1 meV) is less frequent, mostly visible with ferromagnetic tips. Besides, it also appears with low weightage in spectra where all the gap features are visible. Spectral features associated with all three gaps disappear at the bulk Tc. The two smaller gaps seem to be fully gapped. Our results suggest an unconventional superconducting order in this compound: Multiband singlet states
dominated by inter-band pairing or singlet mixed with triplet states, both of which can break the time reversal symmetry.

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Abstract Title: Ultra-long range communication between remote quantum dot clouds mediated by lattice plasmon modes

We report experimental and theoretical studies of photoluminescence from quantum dots (QDs) overlaid on a two-dimensional array of silver nanoparticles. Focusing on micron-scale regions of QDs, which we term clouds, we demonstrate strong coupling can occur with spectral splitting scaling as the square root of the number of excited QDs. Furthermore, by illuminating one cloud region, but examining PL from ever more remote cloud regions, we demonstrate long-range (~ mm) energy propagation. Coupled dipole calculations suggest that long-range polariton modes involving a lattice plasmon mode (LPM) and the QDs are responsible for this phenomenon. We also predict that long range energy transfer between clouds could be observed in our system with a simple experimental setup. Our results suggest an exciting new research direction wherein LPMs or high-quality polaritonic modes can be used to mediate interactions between remote QDs, having various possible applications opto-electronics, sensing and quantum information science.

References:


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Abstract Title: Plasmonics in Fourier Space

Sub-wavelength propagation, localization and routing of light from single emitters are major challenges in quantum nanophotonics, and to this end surface plasmon polaritons at metal-dielectric interface can be effectively harnessed. Among the many configurations in plasmonics, an appropriately prepared dielectric gap between two metal surfaces facilitates enhanced electric and
thermal fields. Such ‘gap-plasmon’ junction can be realized in a variety of 0D, 1D and 2D nanostructures. In this talk, I will give an overview of how Fourier-plane optical microscopy and spectroscopy can be utilized to study: interaction of angular momentum carrying beams with a plasmonic nanowire [1]; molecular fluorescence and Raman emission from gap-plasmon junctions [2,3,4).


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Abstract Title: Engineering photodetection in 2D layered semiconductors and their heterostructures

Recent years have witnessed explosive growth in research on two-dimensional (2D) van der Waals (vdW) materials. A large array of materials with varying properties can benefit applications ranging from electronics and optoelectronics to sensing and spintronics. This talk will describe ongoing experimental efforts in our group on engineering the photodetection performance of optoelectronic devices based on layered 2D vdW semiconductors and their heterostructures.

Ultra-thin 2D transition metal dichalcogenide semiconductors, such as MoS2, not only promise excellent short-channel control for sub-10 nm logic transistors but also exhibit a large photoresponse, high optical absorption, tunability of the band gap and high flexibility coupled with the ability to form defect-free heterointerfaces, making them highly attractive for a wide range of optoelectronic applications. Experimental results highlighting the trade-off between responsivity and speed in gated vdW ReS2 photodetectors through modulation of extrinsic and intrinsic trap concentrations will be presented. Recent results on the photoresponse, including the photovoltaic effect, of WSe2/ReS2 p-n heterojunction diodes and on engineering photo-amplification in electrostatically doped WSe2 n-p-n and interdigitated phototransistors will also be discussed.
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Abstract Title: Ultra-low thermal conductivity in metal chalcogenides for high performance thermoelectric energy conversion

One of the fundamental challenge in developing high-performance thermoelectric materials has been to achieve low lattice thermal conductivity (κL). Extrinsic approach such as formation of nanostructures in thermoelectric matrix have explored significantly for decreasing the κL in Pb and Sn chalcogenides. Further, entropy driven extended solid solutions in pseudo-ternary GeTe-GeSe-GeS system exhibited low κL and high thermoelectric figure of merit (zT) of 2.1. Introduction of point defects, nanoprecipitates and grain boundaries scatter the phonons heavily, but scatters the electrons/holes as well, which decreases carrier mobility. Intrinsic low thermal conductivity is of practical interest due to its robustness against grain size, temperature range and other structural variations. The exploration of new materials with intrinsically low κL along with a microscopic understanding of the underlying correlations among bonding, lattice dynamics and phonon transport is fundamentally important towards designing promising thermoelectric materials. A Zintl compound, TlInTe2, also exhibit ultralow κL due to low energy ratting modes of weakly bound Tl. Recently, we have shown that the localized vibrations of Bi bilayer leading to ultralow lattice thermal conductivity and high thermoelectric performance in weak topological insulator n-type BiSe near room temperature. We demonstrate how the local structural distortions and the associated ferroelectric lattice instability induced soft polar phonons effectively scatter the heat carrying acoustic phonons and help achieve ultralow lattice thermal conductivity in SnTe by engineering the instability near room temperatures via Ge (x = 0-30 mol%) alloying. The local rhombohedral distortions in global cubic Sn1-xGexTe are predominantly associated with local Ge off-centering which forms a short-range chain-like structures and scatter acoustic phonons, resulting in an ultralow lattice thermal conductivity of ~ 0.67 Wm-1K-1, which leads to synergistic boost in the thermoelectric figure of merit, zT, to ~1.6 at 721 K.


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Abstract Title: Painting a reduced graphene oxide pattern on graphene oxide with a conducting atomic force microscope tip.
Graphene, with its strongly inter coupled multi physics parameter space, has been widely investigated for fundamentals and applications. By contrast the properties of its defective derivatives graphene oxide (GO) and reduced GO (rGO) have attracted significantly lesser attention. Especially GO’s status being relegated to an uninteresting intermediary to exfoliated rGO. However the difficulty in making rGO completely oxygen free i.e. pristine graphene has retained interest in knowing the oxygenated counterpart better. Here we begin with a few layered GO and use a conducting atomic force microscope (cAFM) tip to locally reduceGO to rGO, at room temperature. The electrical properties of GO are strongly correlated to its chemical nature i.e. its electrical properties can be tuned according to the relative abundance of the oxygen functional groups. Our results show that the material can change from an insulator (GO) to a semiconductor (rGO) via repeated scanning of a designated area, effectively painting a customized conducting rGO pattern on an insulating GO background.

The controllable tip-assisted reduction process, which is bias and humidity dependent, not allow us to systematically study the electronic, optical and transport properties across the final rGO product and additionally those of the intermediate states(between GO and rGO) and “tune” the relative abundance of sp2 hybridized regions in the rGO device, thereby controlling its overall bandgap and electrical conductivity. Vertical and lateral electrical transport studies mediated via the cAFM tip and source-drain-gate electrode configuration evidenced spatially resolved mechanical and electrical changes on the surface quantifying the physics of electrical transport across the rGO channels. The reduced areas show increase in local conductance over $10^4$ under progressive reduction along with increase in channel conductance $\sim 10^5$. Back gating the rGO channel showed that the minimum conductance point which dominantly had a negative gate bias offset indicating the carrier type in this rGO.

Though the underlying mechanism of this reduction still remains ill understood an interplay of junction water mediated electrochemistry and physical desorption of the oxygen functional groups at the GO surface is suspected. Here we restrict our discussion to the activated electrical transport observed in these rGO channels especially pertaining to applications in optical detection in the IR.

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Abstract Title: When a first-order phase transition becomes zeroth -order and looks like second-order: Kinetic spinodal instabilities at the Mott transition in V2O3

We experimentally establish that the Mott transition at ambient pressure in V2O3 has features of both abrupt and continuous transitions. While strongly hysteretic with a large latent heat, the transition also shows characteristic signatures of continuous transitions---critical slowing down due to diverging susceptibility and purely dissipative, barrier-free phase-ordering. These observations all point toward the presence of spinodal-like singularities at the two boundaries of the metastable phase.
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Abstract Title: Magnetoelectric and Multiferroic properties of Mn4Ta2O9 and Fe4Ta2O9

Soumendra Panja, Jitender Kumar, Luminita Harnagea, Pascal Manuel and Sunil Nair

We report some of our recent work on the corundum related honeycomb magnets Mn4Ta2O9 and Fe4Ta2O9. The Mn member of this family – a linear magnetoelectric – exhibits a remarkably anisotropic magnetization, with the appearance of a weak ferromagnetic component deep within the antiferromagnetically ordered state. Powder neutron diffraction indicates that the magnetic structure comprises of antiferromagnetically coupled ferromagnetic chains of Mn2+ spins aligned along the trigonal c axis, in sharp contrast to that reported in other isostructural members of this family. Magnetic measurements performed under a period electric field indicate that the magnetoelectric response is also anisotropic, with this coupling along the trigonal c axis and that perpendicular to it having different signs. On the other hand, Fe4Ta2O9 is seen to exhibit a series of magnetic transitions, many of which are coupled to the emergence of ferroelectric order, making it the only genuine multiferroic in this material class. We suggest that the observed properties arise as a consequence of an effective reduction in the dimensionality of the magnetic lattice, with the magnetically active Fe2+ ions preferentially occupying a quasi 2D buckled honeycomb structure. The low temperature H-T phase diagram of Fe4Ta2O9 reveals a rich variety of coupled magnetic and ferroelectric phases, in similarity with that observed in the distorted Kagome systems.

References:

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Abstract Title: Study of ultrathin MoS2 based metal-semiconductor contacts and heterojunctions for device applications

Layered transition metal di-chalcogenides (TMDCs) have gained tremendous amount of research interest in past few years owing to their layer dependent optical and electrical properties. These materials have potential to replace silicon technology in CMOS devices. While these semiconductors show potential in nano and opto-electronics, their functionality is limited due to lack of proper understanding of metal contacts on these materials. We have explored the behavior of metals having different work functions such as Ag/Au, Cr/Au, Ni/Au with molybdenum disulfide (MoS2), one member of TMDC family. Ag/Au contact to MoS2 exhibits good ohmic behavior with high current injection efficiency and better linearity and symmetry of I–V curves than Cr/Au and Ni/Au contacts. Ohmic contact study on MoS2 was further studied with Ag/Au contacts using transmission line measurement (TLM). Further, taking Ag/Au as ohmic contact, Pt/MoS2 Schottky barrier diode was fabricated with a high rectification ratio of about 900. This study opens up the possibility of having high quality metal contacts on MoS2 with potential applications in nanoscale devices.
In addition, heterojunctions of MoS2 wide bandgap semiconductor GaN were studied with wide to explore 2D/3D heterojunctions. The use of MoS2, which is a narrow bandgap material and GaN, a wide bandgap material demonstrates an example of a 2D/3D combination matching the general requirements for the heterojunction bipolar transistor. Another important consequence of MoS2/GaN heterojunction is the broad range photodetection. We fabricated exfoliated MoS2/GaN heterojunction using electron beam lithography and it shows rectifying current-voltage characteristics. Band alignment at the interface was studied using KPFM measurements. Further, its photodetection properties were investigated at different wavelengths. Our studies suggest that MoS2/GaN heterojunction could have potential applications for photodetectors.

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Abstract Title: The Puzzle of Thermal Expansion Coefficient of Graphene

The microscopic Grüneisen parameter of phonon modes is positive in most materials leading to increase of mode frequency upon increase of lattice separation, and thus positive thermal expansion coefficient (TEC) is realized. Graphite is long known to possess a negative TEC in the out-of-plane direction at low temperatures, and which changes sign to positive at high temperatures. The magnitude of negative TEC at low temperature is further amplified in graphene. For graphene, the ZA-phonons contribute to large negative microscopic Grüneisen parameter. The estimation of temperature-dependent thermal expansion coefficient (TEC) of graphene is quite challenging. There exist significant disagreements in theoretical calculations and equally with the experimental estimates of this quantity. These disagreements are not simply limited to questioning the magnitude of TEC of graphene, but also its sign. Some recent reports have also claimed a positive TEC for graphene. We demonstrate that these apparent contradictions reported in literature arise from the fact that not only can graphene expand or contract like a crystal, but it can behave like a 2D elastic membrane and it can also deform out-of-plane. Temperature-dependent Raman spectroscopy investigation is supported by studies on mechanical and material properties. We examine the role of mechanical deformations, strain profile, defect density and layer number on the estimation of temperature-dependent thermal expansion coefficient of graphene.

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Abstract Title: Probing individual layers in encapsulated van der Waals heterostructures using electrostatic force microscopy

Electrostatic force microscopy (EFM) is a powerful surface probe, which enables determination of electrical properties, such as surface potentials, work functions, dielectric constants and charge distributions at the nanoscale. In this talk, I will discuss our recent work where we have used EFM as a non-invasive, sub-surface electrical probe to encapsulated van der Waals heterostructure layers.
We demonstrate EFM as a versatile tool to spatially map the constituent layers in a variety of encapsulated van der Waals heterostructures, involving atomically thin layers of graphene, hexagonal boron nitride and transition metal dichalcogenides, where topographic signatures are limited to the top layers alone. The bias dependence of the EFM phase provides a quantitative estimate of the surface potential in various two dimensional layers. The results have important implications in advancing van der Waals epitaxy, while providing a framework by which work functions, doping and charge distributions of individual layers in a heterostructure geometry can be elucidated.

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Abstract Title: Zero modes and monomer correlations on diluted bipartite graphs.

We study the geometry of zero mode wavefunctions in random hopping problems on diluted bipartite graphs, particularly the diluted honeycomb lattice. We obtain numerically exact results for the density of zero modes which are robust to randomness in the hopping amplitudes (hopping disorder), and investigate a possible transition (as a function of vacancy density) in the extent of the maximally localized wavefunctions for these zero modes. An argument relating these properties to the coefficient of the Curie tail in the impurity susceptibility of the diluted Kitaev model is also sketched, as is the connection to monomer correlations in the dimer model defined on the same lattice.

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Abstract Title: Complexity of simultaneous transitions of RENiO3

The origin of simultaneous metal-insulator transition, charge ordering transition, structural symmetry change, and magnetic ordering in bulk rare-earth nickelates (RENiO3) remains puzzling with multiple conflicting reports on the nature of these entangled phase transitions [1]. In this talk, I will discuss our attempts to understand this complex problem by selective suppression of some transitions through heterostructure route. Tailoring an incommensurate heterostructure period relative to the bulk charge ordering pattern, we are able to suppress the charge order transition and structural transition while preserving metal-insulator and antiferromagnetic transitions [2]. Our Hall effect measurement spanning a variety of electronic and magnetic phases of RENiO3 demonstrates that MIT results in only a partially gapped Fermi surface, whereas the full insulating phase forms below the magnetic transition [3].

Abstract Title: Unconventional superconductivity in newly discovered Fe and Cr/Co-based superconductors

Despite extensive research activities worldwide following the discovery of iron-based superconductors (FeSCs), the pairing states and mechanisms of superconductivity in these materials are still not well understood. Recently double layered Fe-based superconductors having quasi-2D crystal structures and Cr-based superconductors with a quasi-1D structure have drawn considerable attention. Here we present characteristics of a few selected Fe- and Cr/Co-based superconducting materials and highlight some of the major unsolved problems, with an emphasis on the superconducting pairing symmetries of these materials [1, 2]. We focus on SR studies of the newly discovered superconductors ACa2Fe4As4F2 (A = K, Rb, and Cs), ThFeAsN, A2Cr3As3 (A = K, Cs) and ThCoC2 which were used to determine the superconducting gap structures, the presence of spin fluctuations, and to search for time-reversal symmetry breaking in the superconducting states. We discuss TF and ZF- SR measurements in the normal and superconducting states of ACa2Fe4As4F2 (A = K, Rb and Cs), ThFeAsN, A2Cr3As3 (A = K and Cs), ThCoC2 and in doped AFe2As2. The superconducting densities of ACa2Fe4As4F2 (A = K, Rb and Cs) can be modelled using two-gap models, which better accounts for the data than single gap s-wave or d-wave models [1]. Here a s + d model can describe the data for all three members of this family of materials, while A = K can also be accounted for by a d + d model and A = Rb can also be fitted with a s + d model. A larger value of 2 =kBTc (6.5) than the 3.53 expected from BCS theory have also been obtained from the SR investigations of all these compounds, indicating strongly coupled superconductivity [1]. The observation of two gaps is very similar to what is often found in FeSCs. Temperature dependence of the magnetic penetration depth measured using the transverse edl SR experiment reveals the evidence of a nodal pairing symmetry for ThCoC2 [2]. In case of ThCoC2, our ab-initio band structures.


Modern nanoscience has focused on two-dimensional (2D) layer structure materials which have garnered tremendous attention due to their unique physical, chemical and electronic properties since the discovery of graphene in 2004. Recent advancement in graphene nanotechnology opens a new avenue of creating 2D bilayer graphene (BLG) intercalates. BLG is semiconductor whose band gap and properties can be tuned by various methods such as doping or applying gate voltage. Here, we show how to tune electronic properties of BLG by intercalation of transition metal (TM) atoms between two monolayer graphene (MLG) using a novel dispersion-corrected first-principle density functional theory approach. We intercalated V, Nb, and Ta and all first row TM atoms between two MLG. We found that the symmetry, the spin, and the concentration of TM atoms in BLG-intercalated materials are the important parameters to control and to obtain a Dirac Cone in their band structures. Our study reveals that the BLG intercalated with one Vanadium (V) atom, BLG-1V, has a Dirac Cone at the K-point. In all the cases, the present DFT calculations show that the 2pz sub-shells of C atoms in graphene and the 3dyz sub-shells of the TM atoms provide the electron density near the Fermi energy level (EF) which controls the material properties. Thus, we show that out-of-plane atoms can influence in-plane electronic densities in BLG and enumerate the conditions necessary to control the Dirac point. This study presents a new strategy for controlling the material properties of BLG so that they exhibit various behaviors, including: metal, semi-metal, and semiconductor by varying the concentration and spin arrangement of the TM atoms in BLG while offering insight into the physical properties of 2D BLG-intercalated materials.

IOP Publishing is one of the world’s foremost publishers within the physical sciences, with over 80 titles covering all aspects of physics. For early career scientists starting out in research, the world of academic publishing can be somewhat confusing. In this talk, directed at PhD students and Postdocs, aims to shed some light on this process and how to navigate it to maximise the impact and visibility your research. This talk will cover topics such as choosing the correct journal for your paper, abstract writing tips, the peer-review process, and publication ethics. More information can be found on our Publishing Support site at https://publishingsupport.iopscience.iop.org/.

Name : Priyanka Mohan
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Abstract Title : Scaling approach to topological phase transitions in 1D systems
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We study topological transitions of two 1D models using an approach similar to that of renormalization group. This method consists of a scaling procedure for inversion symmetric systems. The scaling is done on the curvature function, say Berry curvature, whose integration over the Brillouin zone gives a topological invariant of the system. Using this technique, the ow equations for the different tuning parameters of these models are calculated. The different points obtained from these ow equations corresponds to different topological phases of the model. The topological phase diagrams are constructed using the fact that all the points in the parameter space belonging to a particular topological phase ow towards the same xed point.

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Abstract Title : Parton paradigm for the quantum Hall effect
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The fractional quantum Hall effect (FQHE) in the lowest Landau level (LLL) is understood in a unified manner in terms of composite fermions, which are bound states of electrons and vortices. The strongest states in the LLL are understood as integer quantum Hall states of composite fermions and the compressible 1/2 state as a Fermi liquid of composite fermions. For the FQHE in the second LL, such a unified description does not exist: experimentally observed states are described by different physical mechanisms. In this talk, I will discuss our first steps towards a unified understanding of states in the second LL using the `parton’ theory. I will elucidate in detail our recent work on the parton construction of wave functions to describe many of the FQH states observed in the second LL.

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Abstract Title : Feedback Induced Robotic Topological Insulator
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Abstract – We investigate topological behavior of a staggered 1-D mass-spring chain added to some external feedback. This type of staggered mass-spring system generally possesses a topological state at the one end of the chain. With the feedback, the classical system mimics a non-Hermitian quantum system which is of special interest as such systems can govern new and exotic physical properties which may or may not have direct analogues in the Hermitian counterparts. Here, we see that the feedback induced classical chain shows new exotic topological behavior where the topological state can transport through the 1-D chain. With the increasing feedback strength, the
end state (topological state) switches from left to right and then with more feedback again the end state switches from right to left on the chain. Such observations owing to some robotic emergence which can be viably used in technologies. This switching is also indicated by the different winding properties of eigenvalues and/or eigenfunctions of the system in its quantum analogue. Our model is simple and can be directly studied in laboratories.


Name : Aabhaas V Mallik
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Abstract Title : Understanding the unusual behavior of superfluid density of over doped cuprates
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We theoretically study the superfluid density within the t-J model in the overdoped limit, and find that its temperature dependence has very unusual features. We explain the physical origins of this behavior, and show that this can be used to understand the recent experimental results of Božović et al (Nature 536, 309, 2016) on the overdoped cuprate, LSCO.

Name : Indrajit Maity
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Abstract Title: Low Frequency Modes in Twisted Flatland : Ultra-soft Modes, Superlubricity to Strong Pinning
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We study the effects of twisting on low frequency shear (SM) and layer breathing (LBM) modes in bilayer MoS2 using fully atomistic classical simulations. We show that these low frequency modes are extremely sensitive to twist and can be used to infer the twist angle. We and unique optical “ultra-soft” SMs (frequency < 1 cm\(^{-1}\)) for any non-zero twist, corresponding to an effective translation of the moire superlattice by relative displacement of the constituent layers in a nontrivial way. Additionally, for small twists (\(\theta \leq 3^\circ ; \geq 57^\circ\)) new high-frequency SMs appear identical to those in stable bilayer MoS2 (\(\theta = 0^\circ/60^\circ\)) due to the overwhelming growth of stable stacking regions in relaxed twisted structures. Our study reveals the possibility of an intriguing, \(\theta\) dependent superlubric to pinning behavior and of the existence of ultra-soft modes (which resemble phasons in commensurate structures) in all two-dimensional (2D) materials, which can be used to controllably tune physical properties.

Name : Anushree Datta
Affiliation : Indian Institute of Science Education & Research, Kolkata
Abstract Title: Superconductivity in a disordered vortex lattice
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We study the fate of a type-II s-wave superconductor in a simultaneous presence of orbital magnetic field and disorder. Both orbital field and disorder weaken superconductivity when acting individually. An Orbital magnetic field creates the Abrikosov vortex lattice in a superconductor, which melts with increasing the strength of the field turning the superconductor into a metal. Potential disorder, on the other hand, causes the superconducting phase to undergo a transition to
an insulating state due to localization physics. Within a framework of mean-field theory, we analyze the interplay of these two perturbations which results in an intriguing evolution of the superconductivity. At weak disorder strengths, the superfluid density and the superconducting energy gap collapse with increasing the orbital field simultaneously. However, as the disorder strength increases, the two critical fields corresponding to the vanishing of superfluid density and collapsing of the energy gap, start diverging from each other. We illustrate that this is attributed to a self-consistent spatial re-organization of the order parameters. Our results have important consequences for the strong magnetoresistance peak observed in the disordered Indium Oxide film. We illustrate this by calculating the dynamical conductivity and analyzing its low-frequency behavior. Our results that emphasize the role of fluctuations in the pairing amplitude, capture the non-monotonic evolution of magnetoresistance, consistent with experiments.

Name : Navketan Batra
Affiliation : Indian Institute of science Education & research, Mohali
Abstract Title : Topological Transitions in a Model for Proximity Induced Superconductivity
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Using a prototype model for proximity induced superconductivity on a bilayer square lattice, we show that interlayer tunnelling can drive change in topology of the Bogoliubov quasiparticle bands. Starting with topologically trivial superconductors, transitions to a non-trivial $p_x + ip_y$ state and back to another trivial state are discovered. These phases are then characterized based on their band structure in cylinder geometry and Chern indices. We conclude that the non-trivial triplet $p_x + ip_y$ order we obtain as an energetically favourable state, does not break time reversal! From its edge state spectra, by comparing chiral $p$ wave state to the quantum hall (QH) state, we conclude that the time reversal invariant $p_x + ip_y$ triplet order is in fact a ‘helical’ $p$ wave SC, analogous to the quantum spin hall (QSH) state. We show that these transitions can also be controlled by experimentally viable control parameters, the bandwidth of the metallic layer and the gate potential. Our finding may open up a new route to discover topological superconductors, particularly Helical $p$ wave SC, which are considered to provide a fault-tolerant platform for topological quantum computing.


Name : Manas Ranjan Sahu
Affiliation : IISc
Abstract Title : Andreev reflection mediated unusual electron holemixing at graphene Quantum Hall and superconductor junction
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Two remarkable phenomena of condensed matter physics, the quantum Hall (QH) effect and superconductivity, when combined, can give rise to exotic topological excitations and hold great promises for future quantum computation. Andreev reflection (AR) is the underlying phenomena
that determine the quasiparticle dynamics at the interface of any normal metal and a superconductor. After decades of independent discovery of QH effect and superconductivity, still the AR at the interface of a QH system and a superconductor remain elusive. By shot noise measurements, in a system of graphene QH state connected to a type-2 superconductor MoRe, we shed some light on this problem. We observed Fano factor close to unity when the transport happens via clean edge state and the lids are superconducting. The Fano factor reduces to a very small value, close to zero, above the critical temperature of MoRe. The plateaulconductance for the QH – superconductor is observed to be same as that for a QH - normal metal junction. These observations reveal an unusual mixing of electron and holes due to repetitive AR at the QH-superconductor interface, which in turn keeps the conductance unchanged. Our results also unambiguously demonstrate that, the current is carried by quasiparticles with twice the electron charge. This work will pave the way for exploration of more exotic systems, such as, the junction of a fractional QH state and a superconductor.

Name : Phanibhusan S Mahapatra
Affiliation : IISc
Abstract Title: Thermoelectric twistronics at small-angle twisted bilayer graphene
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Introduction of ‘twist’ or relative rotation between two atomically thin van der Waals (vdW) membranes gives rise to periodic Moiré potential, leading to substantial alteration of the band structure of the planar assembly. These twisted meta-materials, owing to their exceptional tunable nature, have emerged as the ideal platform for studying many novel concepts of condensed matter physics [1,2]. While most of the recent experiments primarily focus on the electronic-wavefunction reconstruction by probing transport properties in the in-plane direction, we report on thermoelectric measurements across the van der Waals gap in twisted bilayer graphene (tBLG) at small twist angle (Ω ∼ 0.60). The cross-plane Seebeck coefficient shows Lifshitz transitions as the band topology changes from electron-like (hole-like) massless Dirac to hole-like (electron-like) massive bands at the van Hove singularity point. Additionally, we observe temperature dependent splitting and strong non-linearity at both half and quarter filling of the lowest bands even at temperatures ∼ 125K, indicating strong electron correlations due to localization of electronic density of states in the system. The twist-controlled cross-plane thermoelectricity in tBLG may provide fundamental insights towards the electron-electron and electron-phonon interactions in Moiré superlattices which can leverage the broad electro structural phase space of layered solids.

Name : Jagannath Sutrada
Affiliation : IISc
Abstract Title: Transport, multifractality, and the breakdown of single-parameter scaling at the localization transition in quasiperiodic systems
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There has been a revival of interest in localization phenomena in quasiperiodic systems with a view to examining how they differ fundamentally from such phenomena in random systems. Motivated by this, we study transport in the quasiperiodic, one-dimensional Aubry-Andre model and its generalizations to two and three dimensions. We study the conductance of open systems, connected to leads, as well as the Thouless conductance, which measures the response of a closed system to boundary perturbations. We find that these conductances show signatures of a metal-insulator transition from an insulator, with localized states, to a metal, with extended states having (a) ballistic transport (one dimension), (b) superdiffusive transport (two dimensions), or (c) diffusive
transport (three dimensions); precisely at the transition, the system displays subdiffusive critical states. We calculate the β function β(g) = d ln(g)/d ln(L) and show that, in one and two dimensions, single-parameter scaling is unable to describe the transition. Furthermore, the conductances show strong nonmonotonic variations with L and an intricate structure of resonant peaks and subpeaks. In one dimension the positions of these peaks can be related precisely to the properties of the number that characterizes the quasiperiodicity of the potential; and the L dependence of the Thouless conductance is multifractal. We find that, as dimension increases, this nonmonotonic dependence of g on L decreases and, in three dimensions, our results for β(g) are reasonably well approximated by single-parameter scaling.

Name : Sujay Ray
Affiliation : IISc
Abstract Title: Role of momentum-dependent self-energies in strange metals and bad insulators with coherent Fermi surface
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In a conventional metallic (insulating) phase, resistivity increases (decreases) with temperature, and a coherent Fermi surface exists (does not exist). In a ‘strange’ metal, the Fermi surface is partially or fully incoherent (non-Fermi liquid), and the resistivity increases linearly with temperature. Here we introduce two opposite concepts. (i) We introduce a ‘strange metal’ state where the resistivity features non-Fermi-liquid behavior, but the Fermi-surface is coherent and analytic. (ii) We also introduce insulating-like transport properties, even in the presence of coherent Fermi-surface. Both results are obtained analytically, as well as numerically within the momentum-resolved density-fluctuation (MRDF) theory in a single band Hubbard model. We calculate self-energy due to itinerant-localized density fluctuations (self-consistently) and find their generic strong momentum-dependence. We demonstrate that both the above results are a manifestation of the momentum-dependence of the self-energy, but at different values of the Hubbard interaction. The results highlight the importance of the non-local self-energy effects in correlated materials, giving unusual results as seen in various experiments.

Name : Anwesha Chattopadhyay
Affiliation : SINP, Kolkata
Abstract Title: Is there a superconducting phase in the half-filled ionic Hubbard model?
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We study the ionic Hubbard model(IHM) in the limit of strong correlations and large ionic potential. In this limit, doublons and holes are energetically expensive on alternate sites and needs to be projected out from the low energy Hilbert space via a generalized similarity transformation. This transformation leads to a modified tJ model with effective next nearest neighbor hopping terms. The couplings of the effective Hamiltonian are renormalized through Gutzwiller approximation which takes into account site dependent projection approximately. We explore the possibilities of d-wave and extended s-wave pairing phases on a 2D square lattice at zero temperature within the Gutzwiller projected renormalized mean field theory. In the sector of solutions that forbid spin ordering, there exists finite nonzero d- wave as well as extended s-wave pairing for U<Δ̃>t with extended s-wave pairing always higher in energy than d-wave pairing. But in the spin resolved renormalized mean field calculation, which allows for AF order along with d-wave or extended s-wave pairing, the SC phase is no longer viable and the system shows a direct transition from an AF ordered phase to a PM band insulator phase with a thin sliver of a half-metallic AF phase close to the AF transition point. We benchmarked the AF Mott insulator to band insulator transition within the Gutzwiller projected
renormalized mean-field theory against the dynamical mean-field theory solved using continuous time quantum Monte Carlo. Our work suggests that the ground-state phase diagram of the IHM at half-filling in the limit of extreme correlations does not have any SC phase. The SC phase seen in the paramagnetic sector is a metastable phase, being higher in energy than the AF Mott insulator phase. To stabilize SC phase as compared to the AF Mott insulator phase, means of magnetic frustration have to be introduced in the Hamiltonian suitably. Introducing next nearest neighbour (nnn) hopping explicitly presents a prospect of obtaining stable SC phase. At reasonably higher values of nnn hopping amplitude, stable SC phase is obtained along with other exotic phases such as AF half-metal phase.

Name: Pooja Saini
Affiliation: University of Hyderabad
Abstract Title: The Rashba & Dresselhaus Spin-Orbit Interactions on an off centre D0 impurity in a 2D gaussian GaAs quantum Dot in the presence of an external magnetic field
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The GS (ground state) binding energy of a hydrogenic-like off centre donor complex placed in a 2 Dimension Gaussian quantum dot GaAs semiconductor is determined incorporating the Rashba and Dresselhaus spin-orbit interactions in the presence of an externally applied magnetic field. A unitary transformation is employed to deal with the the spin-orbit interactions and their effects are incorporated up to second order in the coupling coefficients. The resulting Hamiltonian is solved variationally using a simple wave function. The results indicate that the Rashba spin-orbit interaction and the confining potential reduce the energy of the donor complex whereas the magnetic field enhances it. Interestingly enough, the binding energy is enhanced by the Dresselhaus spin-orbital interaction in the presence of a magnetic field and while it is reduced in the absence of it.
Abstract Title: A novel long-lived gapless plasmon mode in tilted type-II Dirac Semimetal.

We predict the existence of a novel long-lived gapless plasmon mode in a type-II Dirac semimetal. This gapless mode arises from the opposite-phase oscillations of the density fluctuations in the electron and the hole pockets of a type-II DSM. It originates beyond a critical wave-vector along the direction of the tilt axis, owing to the momentum separation of the electron and hole pockets. A similar opposite-phase plasmon mode arises in other multi-component charged fluids as well, but generally it is Landau damped and lies within the particle-hole continuum. In the case of a type-II DSM, the open Fermi surface prohibits low-energy finite momentum single particle excitations, creating a 'gap' in the particle-hole continuum. The gapless plasmon mode lies within this particle-hole continuum gap and, thus, it is protected from Landau damping.

Abstract Title: Magnetocaloric effects from an interplay of magnetic sublattices in Nd2NiMnO6

We present a combined experimental and theoretical study to understand the magnetism and magnetocaloric behavior of the double perovskite Nd2NiMnO6. The magnetic susceptibility data confirms a ferromagnetic transition with $T_C = 195$ K. An additional feature at $T = 25$ K, indicative of antiferromagnetic correlations, is present. A positive magnetocaloric effect (MCE) near $T_c$ and a negative MCE around $T = 25$ K is inferred from the temperature dependence of the change in magnetic entropy at low magnetic fields. The negative MCE peak is suppressed on the application of a magnetic field and can be made to switch to a conventional positive MCE upon increasing magnetic field. We understand and reproduce these features in Monte Carlo simulations of a phenomenological Heisenberg model for Nd2NiMnO6. The validity of the model is tested using Density Functional Theory calculations. We argue that this simple understanding of the experimental observations in terms of two antiferromagnetically coupled sublattices allows these results to be useful across a broader class of magnetocaloric materials.

Abstract Title: Yu-Shiba-Rusinov bound states induced by a spin flipper in the vicinity of a s-wave superconductor

We theoretically study the formation and characteristics of Yu-Shiba-Rusinov bound states [1,2,3] below the superconducting gap using a simple BTK approach [4] in presence of a spin flipper or high spin magnetic impurity. Zero energy YSR peaks are observed in the conductance spectra due to flipping of the magnetic impurity spin. Further, when spin flipper does not flip, a dip forms at $E=0$ in the conductance spectra. This $E=0$ conductance peak is almost quantized at $2e^2/h$ values, however it arises due to non-topological reasons in contrast to the $E=0$ peak formed due to Majorana states.


**Name** : Rajesh Kanna R
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**Abstract Title**: Structural, morphological and optomagtic properties of GO/Nd/Cu-Mn ferrite ternary nanocomposite

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Graphene oxide (GO)/neodymium (Nd)/Cu$_{0.5}$Mn$_{0.5}$Fe$_2$O$_4$ ternary nanocomposite is prepared by the sonochemical and modified Hummer’s method. Crystal structure and the structural parameter of the Cu$_{0.5}$Mn$_{0.5}$Fe$_2$O$_4$ nanoferrite are changed with the addition of Nd$^{3+}$ and GO. Raman active modes of the GO and ferrite system are observed from the Raman spectra. The surface oxidation state (C 1s, O 1s, Cu 2p, Mn 2p, Fe 2p and Nd 3d) and their respective binding energies of the prepared nanocomposite are discussed. Different surface morphology was acquired for the CMF, CMNF, GO and GCMMF ferrite nanocomposite. The absorption of the Cu-Mn nanoferrite (red region) shifted into the blue region with the addition of Nd$^{3+}$ and GO. The magnetic parameters are changed with doping of Nd in CMF and GO in CMNF nanoferrite. The high anisotropy energy values of the CMNF and GCMMF ferrite nanocomposite can be used for electromagnetic wave absorbing application.

**Name** : Mrinal Kanti Giri R
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**Abstract Title**: Quantum Phase Transition in a Multi-component Bose-Einstein Condensate

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We have analytically studied the quantum phase transition from the superfluid phase to the Mott insulator phase for a multi-component Bose-Einstein Condensate (BEC) system in an optical lattice. Here we developed the mean-field theory to study the quantum phase transition. a) First, we have studied the phase transition for the case of the simple Bose-Hubbard model, where we get the two phases which are the Mott Insulator (MI) and the Superfluid (SF) states. b) Secondly, we studied the two species Bose-Hubbard model where we found there exits four states in addition of the two previous states which are the MS (Mott-insulator Superfluid) and the SM (Superfluid Mott-insulator) depending upon the characteristics of the interaction between two species. The meaning of SM is that when the first species is in the superfluid phase and second species is in the Mott insulator phase and vice versa for the region MS. We found that the inter-species interactions indeed can change the position of the phase boundary for the Mott-insulator. c) Next, we take the single species Bose-Hubbard model with three-body interaction, here we find the extension of the Mott-insulating areas and the existence of a fixed point in phase space. Finally, we trying to understand the effect of three-body inter-species interaction term on the phase diagram for the two-component BEC.
We have investigated both the large area and nanostructured interfaces of some common FCC and BCC metals and have found interesting electronic behaviour for some of the nanostructured interfaces. For some such interfaces, presence of extremely flat-bands at Fermi-level indicates the possibility of opening a CDW gap in presence of lattice distortions. Additionally, the electron and hole pockets of the Fermi-surfaces of the nanostructured interface are connected by a Q-vector incommensurate with the lattice periodicity. Such systems are highly optically non-linear at their near-zero epsilon regions.

For metal-semimetal interfaces, we have investigated the TaAs/Au and TaAs/Ag interfaces. The metallic layers have flipped the original spin-polarization of the pristine system, introduce different doping pattern and also modified the underlying symmetry and Fermi surface of the pristine system. We predict presence of hole-doped antiferromagnetism for TaAs/Ag systems.

We analyse the ground-state properties of three-body constrained bosons in a one dimensional optical lattice with staggered hopping analogous to the well known Su-Schrie er-Heeger(SSH) model. By considering attractive and repulsive on-site interactions between the bosons, we obtain the phase diagram which exhibits various quantum phases. Due to the double-well geometry and three-body constraint several gapped phases such as the Mott insulators and dimer/bond-order phases emerge at commensurate densities in the repulsive interaction regime. Attractive interaction leads to the pair formation which leads to the pair bond order phase at unit llng which resembles the valence-bond solid phase of composite bosonic pairs. The pair bond order phase at unit- llng is found to exhibit e active topological properties due to the lattice structure, such as the presence of polarized paired edge states. Finally we study the emergence and breakdown of Thouless charge pumping of bosonic pairs in the bond order phase.

We have formulated a twist operator argument for the geometrically frustrated quantum spin systems on the kagome and triangular lattices, thereby extending the application of the Lieb-Schultz-Mattis (LSM) and Oshikawa-Yamanaka-Affleck (OYA) theorems to these systems. The equivalent large gauge transformation for the geometrically frustrated lattice differs from that for non-frustrated systems due to the existence of multiple sublattices in the unit cell and non-orthogonal basis vectors. Our study for the $S = 1/2$ kagome Heisenberg antiferromagnet at zero external magnetic field gives a criterion for the existence of a two-fold degenerate ground state with a finite
excitation gap and fractionalized excitations. At finite field, we predict various plateaus at fractional magnetisation, in analogy with integer and fractional quantum Hall states of the primary sequence. These plateaux correspond to gapped quantum liquid ground states with a fixed number of singlets and spinons in the unit cell. A similar analysis for the triangular lattice predicts a single fractional magnetization plateau at 1/3. Our results are in broad agreement with numerical and experimental studies.


Name : Indranil Roy
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Abstract Title: Existence of quantum vortex fluid in a very weakly pinned a-MoGe thin film
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One of the manifestations of Quantum Mechanics is zero point fluctuations of atoms, for which materials like liquid He\(^4\) and He\(^3\) do not solidify at ambient pressure down to the lowest temperature, giving rise to a 'Quantum Fluid' at absolute zero. Employing magnetotransport measurements and scanning tunneling spectroscopy down to 300 mK, we have observed that vortices in very weakly pinned a-MoGe thin films can give rise to similar Quantum vortex fluid\(^{[1]}\). It has been previously showed that a vortex solid can melt to an isotropic vortex fluid via an intermediate hexatic fluid phase following the BKTHNY prescription \(^{[2]}\). Here, saturation of electrical resistance to a finite value at low temperatures gives us strong evidence that the two fluid states remain fluid down to absolute zero. Furthermore, scanning tunneling spectroscopy measurements show a soft gap inside the vortex core, which we interpret as arising from large zero point fluctuation of the vortices.


Name : Kamal Das
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Abstract Title: Berry curvature induced thermopower in type-1 & type-11 weyl semimtals
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Berry curvature acts analogous to a magnetic field in the momentum-space, and it modifies the flow of charge carriers and entropy. This induces several intriguing magnetoelectric and magnetothermal transport phenomena in Weyl semimetals. We explore the impact of the Berry curvature and orbital magnetization on the thermopower in tilted type-I and type-II Weyl semimetals, using semiclassical Boltzmann transport formalism. We analytically calculate the full magnetoconductivity matrix and use it to obtain the thermopower matrix for different orientations of the magnetic field \(S(B)\), with respect to the tilt axis. We find that that the tilt of the Weyl nodes induces linear magnetic field terms in the conductivity matrix, as well as in the thermopower matrix. The linear-\(SB\) term appears in the Seebeck coefficients, when the \(SB\)-field is applied along the tilt axis. Applying the magnetic field in a plane perpendicular to the tilt axis results in a quadratic-\(SB\) planar Nernst effect, linear-\(SB\) out-of-plane Nernst effect and quadratic-\(SB\) correction in the Seebeck coefficient.
Abstract Title: Nature of localization-delocalization transition in a two-level system interacting with a phonon bath: A variational treatment with an improved wave function

A dissipative quantum system (QDS) with a small tunneling probability can be modeled by a two-level system (TLS) interacting with a phonon bath. Such a model also provides a basic framework to study many interesting phenomena like decoherence [1,2], impurity dynamics in glasses [3] and metals, molecular transition in liquids, magnetic flux tunneling, Landau-Zener transition etc. It can also mimic a number of other important systems like an Ising model with inverse square interaction in one dimension and quantum heat engine.

A two-level system interacting with a phonon bath is studied using a variational method with an improved trial wave function. It is shown that our results for the ground state energy are in general lower than those obtained by other similar variational methods. It is also demonstrated that there are two possible ground states for the system, one for smaller values of the tunneling matrix element and the other for larger values of it and the system undergoes a localization-delocalization transition as the tunneling matrix element is increased beyond a critical value. Though, in general, there is no dispute about the existence of this transition, the nature of the transition is still not very clear. In the present work, we show, in contrast to the other variational results, that localization-delocalization transition is always smooth in conformity the exact numerical results.


Abstract Title: Role of topology on the work distribution function of anquenched Haldane model of graphene

We investigate the effect of equilibrium topology on the statistics of nonequilibrium work performed during the subsequent unitary evolution, following a sudden quench of the Semenoff mass of the Haldane model. We show that the resulting work distribution function for quenches performed on the Haldane Hamiltonian with broken time-reversal symmetry (TRS) exhibits richer universal characteristics as compared to those performed on the time-reversal symmetric massive graphene limit whose work distribution function we have also evaluated for comparison. Importantly, our results show that the work distribution function exhibits different universal behaviors following the nonequilibrium dynamics of the system for small $\phi$ (argument of complex next nearest neighbor hopping) and large $\phi$ limits, although the two limits belong to the same equilibrium universality class.
We study the effect of Dzyaloshinskii-Moriya interaction on the ground state of kagome Heisenberg antiferromagnet using Schwinger boson mean field theory (SBMFT) framework. We have obtained the zero temperature ground state phase diagram and properties associated with it. We compare our results with other studies and discuss the relevance of our results in experiment.

The GS binding energy of a negative charge hydrogenic donor impurity placed in a 2 dimension GaAs Gaussian quantum dot in the presence of external magnetic field, Rashba and Dresselhaus spin orbital interaction obtained as a function of quantum dot width, Confinement strength, magnetic field, Rashba and dresselhaus parameter by a variational method with a simple wave function. A jastrow-like factor is used to take care of the correlation effect. The effect of quantum dot size and confinement strength on the resultant dipole moment is investigated for different value of Rashba and Dresselhaus paramer.

We report melting of Vortex lattice with increasing magnetic field in amorphous MoGe thin film of thickness 22 nm which is much smaller compared to the bending length of vortices. Therefore, the vortex lattice is 2 dimensional in this film. Here, melting of vortex lattice follows 2 steps BKTHNY melting: (1) Solid to hexatic fluid (appearance of dislocation pairs) and (2) hexatic fluid to isotropic liquid (breaking of dislocation pairs into isolated dislocations: disclination). We show this sequence of phase transition at 0.45 K by combining Magneto-transport and Scanning Tunneling Spectroscopy. However, both the fluid state (hexatic vortex fluid & isotropic vortex liquid) remain fluid till lowest temperature 0.28 K and it evidences from electrical resistance measurement as a function of temperature at different magnetic fields where the resistance saturates to a finite value in these fluid states at low temperatures. Hence, both hexatic vortex fluid and isotropic vortex fluid behave like quantum fluid. We also observed a shallow peak effect in resistivity, linked with second melting line of Vortex lattice. Moreover, from Scanning Tunneling Spectroscopy, a soft gap is observed inside the vortex core. We explain this appearance of soft gap due to zero point fluctuations of vortices.


The spin polarization effects arising due to the reflection and refraction of electrons across a barrier separating metal and semiconductor with Rashba and Dresselhaus spin-orbit interactions are studied. The effects of incident electron energy, incident angle and spin-orbit interactions on the refraction and reflection coefficients and spin polarizability are calculated. The effects of applied voltage, Fermi energy and spin-orbit interactions on current density and differential conductivity are also determined.

The ionic Hubbard model is important because of its diversity of capturing rich phases like correlated band insulator, Mott-insulator, non-trivial metal, magnetic phase, superconducting phase in the different parameter regimes. Ionic Hubbard model is the Hubbard model with staggered onsite potential as add on. We study the ionic Hubbard model on 2D square and 3D cubic lattice with nearest and next nearest neighbour hopping at half-filling. We will use recently developed numerical technique called Mean Field-Monte Carlo (MF-MC) method which is also called Static Path Approximation (SPA). The method allows to extract effective one body spin-Fermion Hamiltonian from the many body ionic Hubbard Hamiltonian by throwing away the quantum fluctuations and retaining only the thermal fluctuations. By means of this technique we can study properties of the model at finite temperatures and access very large system size with manageable computational cost at arbitrary interaction strengths. We present the low temperature $1U$– phase diagram in which there is a correlated non-trivial metallic regime in between correlated band insulator and G-type anti-ferromagnetic Mott insulator and we show that the metallic regime can be extended in the $U$– parameter space by switching on the geometrical frustration by means of next nearest neighbour hopping both on 2D square and 3D cubic lattice. We will analyse the non-trivial metallic phase closely by studying spectral function and optical conductivity. Finally, we will benchmark the results against Perturbed Static Path Approximation (PSPA) calculations, which allows to incorporate quantum fluctuation to the static path calculation (SPA or MF-MC).


[11] Gour Jana, Anamitra Mukherjee, Mean Field-Monte Carlo study of half-filled ionic Hubbard model on 2D square and 3D cubic lattice (under preparation)
The BCS theory [1] establishes superconductivity as arising from the spontaneous breaking of the global U(1) phase rotation symmetry of the electronic state. Indeed, the associated Meissner-Ochsenfeld effect is easily obtained from the phenomenological Abelian Higgs model for Superconductivity by assuming classical fluctuations of the phase and radial components of the Higgs Field. Hansson et al. [2], however, show that superconductivity can possess topological features. These arise from a quantum mechanical treatment that accommodates vortex solutions of the phase variable. Here, we seek the microscopic origins of the vortex term, leading naturally to the collective Hamiltonian obtained by Hansson et al. [2]. Using a unitary RG treatment [4,5], we have shown that the low-energy sector is described by a collective Hamiltonian. This collective Hamiltonian possesses an in-gap spectrum [3], with eigenstates labelled by a zed number of preformed Cooper pairs. However, these states lead neither to a o-diagonal long range order (ODLRO), nor a spatially local order parameter arising from a broken U(1) phase rotation symmetry. Instead, we ed that the eigenstates preserve the U(1) symmetry, and lead to a global (i.e., topological) order parameter. The level-crossing transitions of this collective Hamiltonian possess an emergent SU(2) symmetry and topological WZW term at criticality. Several topological properties of the vortex condensate are also obtained. Such transitions cannot, therefore, be described within the standard GLW paradigm of phase transitions. We have also shown how the BCS ground state is achieved upon including a symmetry breaking term in the RG formalism. We have also shown how thermal and quantum fluctuations a ect the U(1)-symmetric phase.


Bilayers of MoS₂ in the stacking that is found in the bulk have their valence band maximum at point as well as have no net spin splitting at the K point. The former is attributed to the interaction between the out of plane orbitals of the two layers. One way to bring the valance band maximum back to K point in bilayers is by applying bi-axial compressive strain. This increases the interaction between the in plane orbitals. We determined the amount of strain required to shift the valence band maximum from point back to K point. This was found to be 3:5%. Alternate strategies to reduce the strain will be presented. As the presence of inversion symmetry results in a vanishing spin splitting, we will use twisted bilayers to arrive at a net spin splitting.
Nano-magnetism offers intriguing physics and many applications. In order to investigate the quantum magnetism in individual nano-structures high bandwidth and sensitivity SQUIDs operating at low temperatures are the most appropriate probes [1]. Our recent work [2] demonstrates that inductive shunting can eliminate the thermal bistability with good SQUID modulation in voltage resulting into large bandwidth and sensitivity. We use this idea and a newly made setup to study the anisotropic magnetization reversal in individual permalloy needles patterned by electron lithography close to Nb SQUIDs. We compare the results obtained by operating the SQUIDs in both hysteretic and non-hysteretic modes. The obtained behaviour is well described by magnetization reversal through curling mode in an infinite cylinder under Néel-Brown model. We also compare our results with OOMMF [3] simulations on finite length needles. The latter also captures the vortex nucleation and annihilation and thus the observed minor hysteresis loops. Some preliminary measurements on switching statistics on these nano-needles and other nano-structures will also be presented.

1 M. J. Donahue and D. G. Porter, Interagency Report NISTIR 6376 (1999)

A density functional theory (DFT) based computation was conducted to study the electronic band structure, electron density of states (DOS), partial DOS and optical properties of ZnO/ZnS core/shell nanowires. The band structures calculations show a direct band gap of approximately 1.52 eV using generalized gradient approximation (GGA). The dielectric functions, absorption coefficients, refractive indices and optical reflectivities were studied in the energy ranges from 0-30 eV. Our theoretical simulations predict that the absorption process begins from the near infrared region (NIR) while peaks in the ultraviolet (UV) region. The value of refractive index is 1.86 at the zero energy limit. The nature of real part of the dielectric constant suggests that the ZnO/ZnS core/shell nanowire shows metallic nature in the C band of the UV spectrum. The reflectance also reaches its peak of about 24% in the C band of the UV spectrum. The outcome suggests that the ZnO/ZnS core/shell nanowires can be used in the field of photonics where absorption in the ultraviolet region is a requirement.
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Diameter Dependent Quantum Transport Properties of Pd based Core/Shell Structure
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The possibility of tailoring the electronic and transport properties of one dimensional core/shell nanowires by varying the composition and the geometry interface between two materials render them very interesting as building blocks for nano electronic devices. In this regard, nanometarial electrode will play crucial role as electron connector by integrating the individual devices. Here, we have investigated a new metallic core-shell nanowire geometryof that could be obtained experimentally, that is silicon (Si) and germanium (Ge) nanowires with cores constituted by group-10 element Pd. These NWs are optimized with two different diameters of 1.5Å and 2.5Å. The quantum conductance study from electronic band structure properties shows increase in conductivity with the diameter of the nanowire. Furthermore, we have investigated current-voltage (IV) characteristics for the NWs. It has been found that current values in accordance with applied voltage show strong dependence on the diameter of the NWs. Our study on Pd based metallic core/shell NW show a comprehensive picture as possible electron connector in future nano-electronic devices.

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Dynamical preparation of a topological state in a SSH chain under unitary periodic driving
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Considering a BDI symmetric one-dimensional SSH model, we explore the fate of the bulk topological invariant, namely, the winding number under a generic time dependent perturbation; the effective Hamiltonian, that generates the temporal evolution of the initial (ground) state of the completely symmetric initial Hamiltonian, may have the same or different symmetries. We establish that the topological invariant may change in some cases when the effective Hamiltonian (or the Floquet Hamiltonian in the periodic situation when observed stroboscopically) does not respect all BDI symmetries; this is manifested in the associated particle (polarisation) current in the bulk. Our results establish a strong connection between the time evolution of the winding number (thus, the associated transport of currents) and the symmetry of the Hamiltonian generating the time evolution. Exploiting the possibility of temporal variation of the winding number, we have prepared a SSH chain in its it stroboscopic topological state, starting from the trivial one, by application of a periodic perturbation. Furthermore, we also observe stroboscopic topologically protected localised edge states in a long open chain and show that a bulk boundary correspondence survives a unitary non-equilibrium situation in 1D BDI Hamiltonians.
We study an integrable system that is reducible to free fermions by a Jordan-Wigner transformation which is subjected to a Fibonacci driving protocol based on two noncommuting Hamiltonians. In the high-frequency limit $\omega \to \infty$, we show that the system reaches a nonequilibrium steady state, up to some small fluctuations which can be quantified. For each momentum $k$, the trajectory of the stroboscopically observed state lies between two concentric circles on the Bloch sphere; the circles represent the boundaries of the small fluctuations. The residual energy is found to oscillate in a quasiperiodic way between two values which correspond to the two Hamiltonians that define the Fibonacci protocol. These results can be understood in terms of an effective Hamiltonian which simulates the dynamics of the system in the high-frequency limit.

We report detailed magneto-transport measurements on single crystals of the magnetic Weyl semimetal Co3Sn2S2. Recently a large anomalous Hall effect and chiral anomaly have been observed in this material which have been suggested to be related to the large Berry curvature between the Weyl points (Liu et al., Nature Physics (2018)). Another effect expected to result from the topological band structure of magnetic Weyl materials is the planar Hall effect. In this work we report observation of this intrinsic effect in single crystals of Co3Sn2S2. Together with the large anomalous Hall conductivity, this further demonstrates the Topological character of Co3Sn2S2.

Correlation effects are important in governing the metal-insulator (M-I) transition in strongly correlated oxides systems. Particularly, understanding the conductivity dynamics of these materials at the transition from metal to insulating phase is long standing interest in condensed matter physics. In this aspect, perovskite vanadates are the fascinating materials in the context of understanding fundamental electron correlations as well as the optical transparency which has the technological applications. In this communication, we present THz conductivity study of CaVO$_3$ thin film grown on (LaAlO$_3$)$_{0.3}$(Sr$_2$TaAlO$_6$)$_{0.7}$(LSAT (100)) substrate using pulsed laser deposition technique. CaVO$_3$ is a correlated perovskite oxide with 3$d^1$ electronic configuration which is responsible for the conduction in the material. The thickness dependence of electronic properties of CVO suggests the occurrence of metal-insulator transition below 30 nm. In order to probe the low energy carrier dynamics at this transition we employed THz time domain spectroscopy. It is found that the real part of the THz conductivity decreases with increasing frequency and imaginary part conductivity is positive throughout the temperature range of 5-300 K. The experimental results modeled using the Drude theory provides an important information about the M-I transition in these materials. The plasma frequency increases with decreasing temperature in the metallic regime indicates the increase in conductivity and the scattering rate increases rapidly at transition indicating carriers are suffering from collisions which leads to carrier localization at M-I transition.
Tolerance factor concepts have dictated the favoured structure in inorganic perovskites of the form ABX3. The recent interest in hybrid perovskites which have a molecule at the A-site have brought forth the need to extend the concepts beyond those involving only ionic radii that one has for the inorganic perovskites. We have considered two limiting cases as examples and discuss the additional considerations that drive structural distortions in this class of material.

The size dependence of the electronic properties of semiconductor nanocrystals have been investigated for many years [1]. The sizes up to which one has a deviation in the electronic structure from the bulk limit depend on the Bohr radius of the semiconductors. The recent interest in the two dimensional transition metal dichalcogenides has led to an analogous question being asked for this class of materials which have weak van der Waals interactions between the layers. In this work we will present a microscopic model which captures the behaviour and discusses the origin.


We study the quantum phase transitions in a system of coupled cavity array consisting of three-level atom in each cavity. By tuning the coupling strengths between the different levels of atom and the photon tunneling rates between cavities, we obtain the complete phase diagram both in one and two dimensions. We show that for a particular choice of parameters the phase diagram exhibits formation of polariton pairs which leads to the pair superfluid phase of polaritons occurring between the empty state and the Mott insulating state at polariton density equal to two. This interesting phenomena is understood by utilising the density matrix renormalization group method and the cluster mean field theory approach.
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Abstract Title: Scaling Theory for Mott Hubbard Transitions
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We present a zero temperature nonperturbative renormalization group (RG) theory of the electronic Hubbard model in two dimensions on a square lattice, leading to effective Hamiltonians there associated many body eigenfunctions, eigen-energies across various doping values. We have benchmarked the ground state energy, doublon fraction at half filling and 1/8 doping and have found remarkable agreement with the results obtained from various other numerical techniques. The RG treat quantum fluctuations by iteratively applying unitary operations which decouples one electronic state at every step. The resulting phase diagram thus possess the quantum fluctuation energy scale ($\omega$) as one of its axes. A relation is derived between $\omega$ and the effective temperature scale upto which gapless, as well as emergent gapped, phases can be obtained. We find that the half-filled Mott transition involves passage from a gapless non-Fermi liquid to a gapped Mott liquid through a pseudogapped phase upon lowering the fluctuation scale. This Mott liquid is identified to be precursor to a superconductor due to presence of preformed zero momentum pairs. Upon doping, we show the collapse of the Mott liquid at quantum critical point possessing d-wave structure in k-space: a nodal non-Fermi liquid with large superconducting fluctuations, and pre-formed Cooper pairs lying within spin-pseudogapped parts of k-space located away from the nodes. The onset superconducting scale further is found to follow Holmes Law with a nodal Marginal Fermi liquid metal displaying Planckian dissipation. By allowing for symmetry breaking, we find an emergent d-wave superconducting phase surrounding the quantum critical point. We also obtain a hierarchy of onset temperature scales for the pseudogap, Mott liquid and superconducting phases which are qualitatively consistent with those obtained from experimental studies on the cuprates. The results offers understanding into origin of high Tc Superconductivity in doped Mott Hubbard system.

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Abstract Title: Thermal transport properties of monolayer AlN-a first principles study
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Two dimensional materials have gained a great deal of attention due to their various unique properties related to the low dimensionality. Recently, the application of 2D materials in thermal management has become one of the major focal points of cutting-edge research. The phonon transport property is fundamental for understanding a material and predicting its potential application in micro/nano devices. In this work, we have studied the thermal transport properties of hexagonal AlN monolayer using DFT based calculation in combination with the iterative solution of phonon Boltzmann transport equation. At room temperature (300 K), the lattice thermal conductivity (Klat) of AlN monolayer is found to be about 306.434 W/m-K which is greatly higher than many other 2D materials. The variation of thermal conductivity with temperature perfectly follows the typical 1/T nature. The contributions from different phonon modes are analysed which reveals that the low frequency acoustics modes mostly contribute to the Klat. The reason behind this large contribution of the acoustics modes is further analysed in terms of phonon lifetime and per mode contribution in the anharmonic phase space of three phonon scattering processes. The results show that the flexural acoustic (FA) mode has the longest lifetime but may convert into other acoustic and optical modes through three phonon scattering process, enhancing their contribution in the Klat. Finally, the mean free path distribution of different phonon modes are also studied which reveals the size effect for AlN monolayer to manipulate its Klat. Our results shed light on the phonon transport properties of AlN monolayer and foreshow its possible application for thermal management.
A persistent low-frequency negative capacitance (NC) dispersion has been detected in half-metallic magnetite (Fe3O4) nanoparticles having a size-variation: 13-236 nm; under application of moderate positive DC bias, probed via impedance spectroscopy. A 3D Cole-Cole plot fitting technique has been used employing Havriliak-Negami model to recapitulate the relaxation time ($\tau$) of the associated oscillating dipoles, related shape-parameters ($\alpha, \beta$) and resistivity for different sizes. Universal Debye relaxation (UDR) theory requires a modification to deal with the shifted static NC-dispersion plane in materials showing both +ve and –ve capacitance about a transition-frequency ($f_0$). A generalized dispersion-formula has been proposed in this regard to fit the complete data of +ve and –ve capacitance regime including the diverging transition-point. In addition, a comprehensive model has been discussed to differentiate the continuous transition from –ve to +ve capacitance and capacitive switching. A consistent blue-shift of ‘$f_0$’ was observed with increasing external electric field and decreasing particle-size. An inherent non-stoichiometry due to iron-vacancies [Fe3(1-δ)O4] detraps holes and builds up p-type nature, which consequently gives rise to more covalent and heavier dipoles slowing down the Maxwell-Wagner interfacial polarization dynamics. This combinational effect has been apprehended for the localized charge recombination and stabilization of NC.


Abstract

Electrostatic force microscopy (EFM) has emerged as a powerful probing technique to investigate the surface potentials and charge distributions in various 2D materials and heterostructures. In this work, EFM has been employed to explore the surface potential of graphene and transition metal dichalcogenides(TMDCs) encapsulated by hBN. EFM phase variation with voltage indicates the effect of substrate doping and ambient environment on the surface potential of graphene.

Fig.1: (a) Optical micrograph and (b) AFM topography of a heterostructure stack. (c)-(f) show the EFM phase images of the heterostructure. In (c), red and yellow dashed lines indicate the bottom and top hBN layers respectively(e) Blue dashed lines indicate single layer graphene (SLG). The hBN/SLG/hBN and hBN/SLG/SiO2 regions indicated as A and B, show distinct EFM phase contrast (c-f). (g)

EFM phase plotted as a function of bias voltage for regions A and B. Bias voltage is given to sample through heavily doped Si keeping the AFM tip grounded. EFM phase is fitted using the equation

$$\Delta \varphi = - \tan^{-1} \frac{Q_{\text{cant}}}{k} \frac{\partial^2 C}{\partial z^2} (V - V_s)^2$$

$V_s$ corresponds to surface potential, $Q_{\text{cant}}$, $k$ are quality factor and spring constant of the cantilever respectively. $V_s$ is obtained to be -0.7 V and -0.9 V in regions A and B respectively. We attribute this difference to doping from charge traps in the substrate. In region B, SiO2 beneath the graphene has positive trap charges which modulate the chemical potential of graphene resulting in n-doping. In region A, the bottom hBN layer screens the effect of dangling bonds and trap charges of SiO2, while the effect of the ambient environment on the chemical potential of graphene is reduced by the top hBN. Raman 2D peak for the two regions ensure the effect of SiO2 as shown in Fig 1(g) inset. Blue shift and enhancement of FWHM 2D peak (red) of graphene indicate the doping from SiO2.

Fig.2 (a) Optical image of an encapsulated few layer MoS2-WSe2 heterostructure (b) AFM topography (c-f) EFM phase at different voltages. Surface potential obtained shows that $V_s$ for MoS2 is -0.27 V and for WSe2 is -0.18 V and corresponding work functions obtained indicate the effect of interlayer charge transfer.
between the TMDCs. This study provides insight on the interlayer coupling among 2D materials which may find applications in electronics and optoelectronic devices.

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Name: Anshu Sirohi
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Abstract Title: Direct evidence of two-gap superconductivity in Mo8Ga41
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Mo8Ga41 is a compound of endohedral gallide family and the compound of the highest critical temperature in the family. The highest critical temperature in this compound is manifested by the competition between valence electron counts and the lattice structure. Hence, it goes against the superconducting rules proposed by Mathias. Here, we have investigated the superconducting state in detail by scanning tunneling microscope (STM) and found that this compound manifest two-band superconductivity. In this talk, I will show clear and direct evidence of two gap superconductivity in Mo8Ga41. Both the gaps are found to be conventional in nature and the electron-phonon coupling falls in the weak coupling limit within the BCS theory. In addition, I will also show that the superconductivity is governed by the site-selective mechanism.

![Graphs showing superconductivity](image)

### Name: Tanweer Ahmed
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**Abstract Title:** Structural inhomogeneity driven current relaxation in hBN encapsulated MoS\(_2\) FETs
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Combining atomically thin layers of van der Waals (vdW) materials in a chosen vertical sequence to form a heterostructure is accepted as general route to create devices with desired functionalities. While this method aims to exploit the individual properties of partnering layers, strong inter-layer coupling can significantly alter their electronic and optical properties. Here we explored the impact of the vdW epitaxy on electrical transport in atomically thin molybdenum disulphide (MoS\(_2\)) encapsulated by crystalline film of hBN. We observe a time dependent current relaxation following thermal cycling that becomes less pronounced for thicker (trilayer) MoS\(_2\)crystals. Raman spectroscopy indicate structural inhomogeneity caused by a structural phase resembling to octahedral (1T') phase as a driving mechanism for current relaxation. Our electrical transport experiments also suggest that this phase is possibly distributed as disconnected patches creating a 2D array of random quantum dots (QD) only in the heterostructure region. Our work adds to a better understanding of the effects of van der Waals hetero-epitaxy driven inter-layer interactions in atomically thin MoS\(_2\).

### Name: Amrita Mukherjee
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We investigate a simple tight-binding Hamiltonian to understand the stability of spin-polarized transport of states with an arbitrary spin content in the presence of disorder. The general spin state is made to pass through a linear chain of magnetic atoms, and the localization lengths are computed. Depending on the value of spin, the chain of magnetic atoms unravels a hidden transverse dimensionality that can be exploited to engineer energy regimes where only a selected spin state is allowed to retain large localization lengths. We carry out a numerical analysis to understand the roles played by the spin projections in different energy regimes of the spectrum. For this purpose, we introduce a new measure, dubbed spin-resolved localization length. We study uncorrelated disorder in the potential profile offered by the magnetic substrate or in the orientations of the magnetic moments concerning a given direction in space. Our results show that the spin filtering effect is robust against weak disorder and hence the proposed system should be a good candidate model for experimental realizations of spin-selective transport devices.

### Name: Sudhir Kumar Sahu
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**Abstract Title:** Cavity-optomechanical devices based on exfoliable superconducting crystals of BSCCO
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There has been a keen interest in exploring 2-dimensional materials for various device applications. Their electrical property spans over a wide spectrum ranging from insulating, semiconducting, metallic to superconducting behavior. From the family of the exfoliated thin crystals, the superconducting crystals are most attractive for developing cavity optomechanical devices. In this direction, we probe the mechanical properties of the exfoliated crystals of BSCCO. We perform mechanical compliance measurements using the nanoindentation technique and determine the pre-stress and Young's modulus of rigidity. While the pre-stress spreads over significantly from 5 \(\mu\text{N/m}^2\) - 50 \(\mu\text{N/m}^3\), Young's modulus lies in the range of 20 GPa to 30 GPa and does not show any prominent thickness dependence.

To develop cavity-optomechanical devices, we couple their mechanics to a superconducting coplanar waveguide microwave cavity. We demonstrate mechanical frequency tunability with
external dc-bias voltage and quality factors up to 36600. Our spectroscopic and time-domain measurements show that mechanical dissipation in these systems is limited by the contact resistance arising from resistive outer layers. The temperature dependence of dissipation indicates the presence of tunneling states, further suggesting that their intrinsic performance could be as good as other two-dimensional atomic crystals such as graphene.

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Abstract Title: Low temperature saturation of phase coherence length in topological insulators
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Topological insulators (TIs) are a new class of materials characterised by linear gapless surface states, which emerge in the bulk band gap due to non-trivial topology of the band structure. Topological protection of the surface states makes these materials a strong contender as the building blocks of qubits, which require long phase coherence length for error tolerant quantum computation. Hence it is critical to understand the mechanisms responsible of dephasing or decoherence, in the surface states of TIs, which is equivalent to the loss of information. The decoherence of the surface carriers of topological insulators have been investigated by performing both magneto-resistance (MR) and conductance fluctuations (CF) measurements. The phase breaking length obtained independently from MR and CF, displays a saturation at low temperature (T) in both exfoliated TIs as well as epitaxially grown films, which is often attributed to spin-flip scattering processes. However, the magnitude of conductance fluctuations displays a factor of two reduction as perpendicular magnetic field (B) is increased, and a saturation with reducing T at a large, fixed B indicating that the observed behaviour of does not arise from spin-flip scattering. Our experiments suggest that the dephasing mechanism responsible for the saturation of arises from unscreened electromagnetic potential fluctuations, originating from the uncompensated charged disorders present in the bulk of the TIs.

Name: Mithun K P
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Abstract Title: Ultrafast Time Resolved Dynamics of Surface and Bulk Carriers in Bismuth Telluride Nanoflakes Studied Using Optical Pump Terahertz Probe Spectroscopy
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Using ultrafast Optical Pump Terahertz Probe (OPTP) spectroscopy, we study the relaxation dynamics of photoexcited carriers in Bismuth Telluride (Bi_2 Te_3)Nanoflakes— a prominent candidate among the three dimensional Topological Insulators (TIs)(1). After photoexcitation using 800nm pump pulse, we observe an increase in the photoinduced conductivity(\Delta \sigma(\omega)), due to the absorption of the THz radiation by the photoexcited carriers. The time evolution of the differential conductivity (\Delta \sigma(t)=\sigma^\star(t)-\sigma_0) shows a sign change from positive to negative highlighting the contribution from the semiconducting bulk and metallic surface states in the carrier relaxation dynamics respectively(2). However, in the frequency domain, the differential conductivity spectra (\Delta \sigma(\omega)) shows a unique behaviour with the real and imaginary part of conductivity flipping sign as carriers relax back to their equilibrium distribution. We attempt to explain such a behaviour by invoking two different Drude response functions for the carriers arising from the bulk and surface states during the relaxation process. Furthermore, we explain the time evolved Optical Pump Terahertz Probe (OPTP) dynamics by attributing them to the intraband contributions of the surface and bulk conductivity derived using Boltzmann Transport equation (BTE) which shows consistent results with the Two-Drude response model of \Delta \sigma(\omega) in the frequency space.
We theoretically study the spin-phonon coupling in Pr$\text{Zr}_2\text{O}_7$, which is a candidate for spin-liquid. Strong spin-orbit coupling in this material gives rise to a low energy effective spin degrees of freedom which forms a non-Kramers doublet. We want to study, how this doublet behaves in the presence of lattice distortion. Especially, whether the spin-phonon coupling leads to any first order structural transition. Also we are interested in calculating Raman scattering cross-section in this material which can give us enough information about how the phase transition is driven.
The macroscopic optical properties of monolayer PtP$_2$ have been investigated using first principles computations based on density functional theory (DFT). The dielectric function, refractive index, absorption coefficient and electron energy loss spectrum were calculated in the energy range between 0 to 30 eV. The results show that a small amount of absorption starts in the infrared (IR) region and peaks in the vacuum ultraviolet region i.e. 100-190 nm. Also, in the ultraviolet region, absorption is highly selective. The refractive index is 2.3 for PtP$_2$ monolayer. The semi metallic nature for PtP$_2$ can be characterized from the real dielectric constant. The higher value of static dielectric constant is evocative of enhanced shielding effects. From the absorption capabilities and high refractive index, PtP$_2$ is suitable candidate for some optoelectronic devices.

Carbon is a fundamental element of the periodic table which can exist in different forms like graphite (3D), graphene (2D) or carbon nanotube(1D). Among these class of carbon compounds, the Planar T Graphene is a 2D stable tetra ring arrangement of carbon atoms. It has one sublattice in the unit cell. Planar T graphene has no linear dispersion like normal graphene. The band structure of planar T graphene is like metal but buckled T graphene is a semimetal with zero band gap. This buckled T graphene band structure has a crossing point near Fermi surface and it shows linear dispersion at n and n$^*$ bands. It is the host of Dirac fermion i.e., T graphene can also sustain the Dirac electrons under a certain pressure without hexagonal symmetry.[1]

Introduction of the defect in 2D planar and buckled T graphene are important for modifying the electronic structure, band structure, and magnetic properties, transport properties like any other condensed matter systems. Substitution and adatom introduction on planar T graphene Sheet can influence the non magnetic properties of carbons with a different type of hybridization. Using Density Functional Theory (DFT) one can address the problem with substitution and doping of different kind of elements from periodic table. In our work we are trying to see how the electronic and magnetic properties change or varying with doping of elements in T graphene sheet.

Both compressive and tensile strain converts the insulating trivial phase to non-trivial topological insulating phase. The effective tight binding (TB) with a minimal basis set is employed to study the effect of hybridization under strain. The low symmetry Hamiltonian are mapped on-to minimum basis set Hamiltonian, which essentially captures the same features of original Hamiltonian. Further a simple and very efficient TB model is constructed for slab structure to study the invariant surface states to substantiate the topological phase.

Name: Animesh Nanda
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Abstract Title: Phases and Phase Transitions in Anisotropic JK Model
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It has been shown Kitaev (K) model supplemented by Heisenberg (J) and symmetric dipolar interaction ( ), namely JK model is the most relevant symmetry allowed Hamiltonian for the Kitaev material [1] [2]. There exist many studies to determine the different phases of this model in the different parameter regimes [2], near the isotropic Kitaev limit. In this work, we study an anisotropic Kitaev limit of this model, namely the Toric Code (TC) limit. This is an interesting analytically tractable limit where we can comment about the phases and phase transitions. We can reproduce different phases of the isotropic limit of the JK (Heisenberg Kitaev part) model, in the JK part of the full anisotropic Hamiltonian both in the Ferromagnetic and Anti-Ferromagnetickitaev limit [3]. We obtain different phases in the K part of the Hamiltonian. Furthermore, we comment about the phase transitions from the Spin Liquid ground state (TC limit) to magnetically ordered states once we include J and contributions.


3. Gotfryd, Rusnacko,ˇ Wohlfeld, Jackeli, Chaloupka, and Oles;´ Phase diagram and spin correlation of the Kitaev-Heisenberg model: Importance of quantum effects, Phys. Rev. B 95,024426
Raman spectroscopy can be used to probe spin phonon coupling for detecting unconventional ordering in materials. Ni Ga\textsubscript{2} S\textsubscript{4} is one such compound that is expected to show spin nematic ordering. In this compound, Ni forms triangular lattice. Strong coupling expansion shows that the effective Hamiltonian is a spin-1 bi-linear bi-quadratic model. The spin phonon coupling can help change the coupling strengths in the effective Hamiltonian. We intend to study the effect of this magneto-elastic coupling on the fractional change in sound speed in the nematic phase and understand the implications for observations through Raman spectroscopy.

The universal quantization of thermal conductance provides information on the topological order of a state beyond electrical conductance. Such measurements have become possible only recently, and have revealed, in particular, that the value of the observed thermal conductance of the 5/2 state is not consistent with either the Pfaffian or the anti-Pfaffian model, motivating several theoretical articles. The analysis of the experiments has been made complicated by the presence of counter-propagating edge channels arising from edge reconstruction, an inevitable consequence of separating the dopant layer from the GaAs quantum well and the resulting soft confining potential. Here we have performed the thermal conductance measurement in graphene having atomically sharp confining potential by using sensitive noise thermometry setup. The measurements are done on hexagonal boron nitride encapsulated graphene devices gated by either SiO\textsubscript{2}/Si or graphite back gate. We find the quantization of thermal conductance within 5% accuracy for \(\nu = 1, 4/3, 2\) and 6 plateaus emphasizing the universality of flow of information irrespective of the nature of quasiparticle. These thermal transport measurements in graphene quantum Hall will pave the way to get new insight into exotic systems like even denominator quantum Hall fractions in graphene.

Phosphorene has emerged as an important material in the family of two-dimensional layered materials with several potential applications including field effect transistors, photo-voltaic p-n junctions etc. This is due to the fact that it not only possesses a direct band gap ranging from 0.3\{2.1 eV (depending on the number of layers) but also a high carrier mobility (1000 cm\textsuperscript{2}/Vs for the holes). Native point defects \[1, 2\] can induce states within the electronic band gap of phosphorene and influence its electrical, optical and magnetic properties. The puckered structure of phosphorene accommodates different kinds of native point defects. We have studied the stability and electronic properties of vacancy and self-interstitial defects in mono- and bilayer phosphorene. We calculate the formation energies and charge transition levels of these defects using the combined formalism of density functional theory and GW. Our calculations show that these defects have low formation energies making them easy to form. Furthermore, phosphorus vacancy shows acceptor type
behaviour which could explain the p-type conductivity in phosphorene. On the other hand, interstitial defect can act as both acceptor and donor type defect.

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**Abstract Title**: Anomalous electron transport in epitaxial NdNiO3 films
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The origin of simultaneous electronic, structural and magnetic transition in bulk $\text{RENiO}_3$ is very puzzling and many conflicting results have been reported about the nature of these entangled phase transitions [1]. Our magneto transport measurements on ultra-thin films of NdNiO3 modulated by epitaxial strain reveal a crossover of Hall coefficient ($RH$) from hole to electron-like behavior across the Neel temperature, emphasizing the antiferromagnetic ordering is connected to a spin-density wave transition. These measurements further reveal cuprate-like $T$-dependence in resistivity and Hall angle in metallic phase of these films under tensile strain. $RH$ in metallic phase also shows a systematic reduction with the decrease of tensile strain and becomes eventually negative for large compressive strain. Such $n$-type metallic behavior in the nickelates family has not been reported so far and emphasizes the utility of epitaxial strain in Fermi surface engineering of complex oxides. The compressive strain also reduces the flat part of the hole Fermi surface, causing the suppression of antiferromagnetic ordering.


**Name** : Surajit Bera
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**Abstract Title**: Exact diagonalization study of low-energy spectra and thermalization across a non-Fermi liquid to Fermi liquid transition
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We study non-equilibrium dynamics and many-body energy spectra near the ground state of a strongly interacting large-N disordered fermionic model. The model is related to Sachdev-Ye-Kitaev (SYK) model and can be tuned to undergo a quantum phase transition (QPT) in the large-N limit between a SYK non-Fermi liquid (NFL), having nite zero-temperature residual entropy, to a weakly interacting Fermi liquid phase (FL) with no residual entropy. We study many-body level spacing, single-particle spectral function, thermal entropy and entanglement properties of low-energy eigenstates across the NFL-FL transition beyond large-N via numerical exact diagonalization. We also construct the effective low-energy eld theory across the QPT by considering ucuations around the large-N limit. Furthermore, we explore out-of-equilibrium dynamics and thermalization after a quench across the QPT through time-evolution of entanglement entropy and non-equilibrium Green’s functions.
The effects of electron-electron interaction, Rashba spin-orbit interaction and Dresselhaus spin-orbit interaction on the heat capacity and entropy of a two-electron parabolic quantum dot are studied in the presence of a magnetic field and at finite temperature. The effect of the electron-electron interaction is studied by using an exactly soluble model potential namely the Johnson-Payne potential, while the Rashba and Dresselhaus spin-orbit interactions are treated by unitary transformations. It is observed that the heat capacity has a double peak structure as a function of the magnetic field at singlet-triplet transition point and the e-e interaction shifts the peaks to lower magnetic fields. It is also shown that the e-e interaction reduces the heat capacity in the low temperature regime while in the high temperature regime it enhances it. Interestingly, however, the electron-electron interaction does not have any effect on the heat capacity in the high field regime. The entropy is found to show a single peak as a function of magnetic field at the singlet-triplet transition point. RSOI reduces the heat capacity and DSOI enhances it whereas the opposite effect is observed in the case of entropy. The effect of zero field spin-splitting has been clearly demonstrated in the temperature behaviour of both heat capacity and entropy.

Spinless Falicov-Kimball model (FK model) can be studied exactly in 1D, and by dynamic mean eld theory in two and higher dimensions. Classical Monte Carlo methods have been implemented to study this model in 2D at mainly half-lling. Away from half- lling, slow Monte Carlo updates make it non-ergodic at low temperature. Hence it becomes expensive to study phase transitions by Monte Carlo methods away from half- lling. In this work, we study this problem by modeling the phase transitions as classi cation problem within the Machine learning method process, with the hope to easily reach the uncharted fractional lling factors. Classi cation problem is dealt with using one of the cient clas-siication algorithm, namely multi-layers ‘convolutional neural network’ (CNN). We nd that both classical and quantum phase transition points can be quantitatively predicted by this Machine learning method. We extended this to calculate regions away from half- lling where the usual Monte Carlo methods often fail. Our result gives interested phase diagram away from half- lling.

In 3d transition metal oxides, the interplay between spin, orbit and charge degrees of freedom leads to intriguing phenomena such as metal-insulator transition, superconductivity, two-dimensional electron gas, etc. One such example is the strongly correlated ruthenate Sr₂RuO₄. The rst principles study shows that the Ru t₂g orbitals are playing most crucial role at the Fermi level due to their high density of states hence making it a strongly correlated quasi-two-dimensional system . We have obtained the magnetic phase diagram of Sr₂RuO₄ by solving the two-dimensional multi-band Hubbard model in the Hartree-Fock mean-eld approach at zero temperature. In relatively low carrier regions the FM phase is found to be stable, whereas the
AFM phase stabilises around half-ling. The FM domain extends in the phase diagram as the Hund’s coupling increases revealing that it favours the FM ordering.

Name : Naveen Nishad
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Abstract Title: Scaling of loschmidt echo in boundary driven critical Z3 clock model
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Loschmidt echo for critical quantum systems when driven periodically from boundary shows simple scaling behaviour. The scaling exponent depends on following characteristic time scales of system - T, tKZ, and tb which are decided by time period of driving, type of drive, Hamiltonian and amplitude of driving (hb) respectively. For the step drive loschmidt scaling exponent depends on the tb hbb while for the sin drive tb get replaced by Kibble-Zurek time scale tKZ and this emergent time scale is given by tKZ. Scaling in the slow driving regime can be explained using boundary CFT while for the fast driving regime, it can be understood using high frequency expansion used in Floquet theory. In earlier works, this scaling has been studied for the integrable system i.e. Tranverse Field Ising Chain. We have studied this numerically using tDMRG in the case of one dimensional Z3 Potts model which is a non-trivial model as it can not be represented in terms of free fermions. The scaling exponents that we got are in close agreement with exponents in boundary CFT literature for potts model.

Name : Surabhi Saha
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Abstract Title: Attenuated wavefunctions of a two-level system with time-dependent gain and loss
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Traditionally, we impose Hermiticity condition on Hamiltonians describing physical systems, since it ensures real eigenvalues and conserved probability density. There has been a recent outburst of theoretical and experimental investigations on non-Hermitian Hamiltonians in quantum optics and condensed matter systems where interesting physical properties are demonstrated with and without real eigenvalues. In this project, I study a novel two-level system with balanced gain and loss terms. The two levels are coupled by a tunneling term Ab and are given onsite potential it, where is a constant and t is the time. We nd that the system has an interesting solution when the parameters are tuned to the condition \( A^2 = 2n \) where n is a positive integer. More speciﬁcally, the time-dependent Schrodinger equation of each component of wavefunction turns to be a Harmonic oscillator in time. Hence the wavefunctions become Gaussian in time weighted by the Hermite polynomials.
**Name**: Partha Sarathi Rana  
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**Abstract Title**: Theoretical study of unconventional Superconductivity in an Ising superconductor MoS$_2$  
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We study unconventional superconductivity in Ising-superconductor MoS2(single layer) in presence of borken inversion symmetry and therefore strong Rashba spin-orbit coupling, provided by heavy Mo atoms, near zero temperature. We have additional Zeeman coupling in our system. The SOC splits the con-duction band and results in spin polarisation and spin-momentum locking, that mimics the formation of cooper pair. Due to this mechanism the crit-ical magnteic eld for this system(in SC regime) is larger than the pauli limit, predicted by conventional BCS theory. Our approach is to employ spin-uctuation mechanism to determine the parity and pairing strength of cooper pair wavefuction. We keep focus on the Competition between singlet and triplet channel superconductivity, chemical potential dependence of par-ity, mixing parity pattern and dependence of chemical potential,Hubbard interaction and stability of superconductivity in different channels to have an insight into enhancement of critical magnetitic field.

**Name**: Arup Kumar Pal  
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**Abstract Title**: Edge dynamics studied by shot noise measurement at the graphene PN junction  
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Mach-Zehnder interferometers in mesoscopic systems are considered one of the promising waystostudy the fractional statistics and quantum entanglement. In these interferometers, the quantum Hall edge states formed at high magnetic field are used as the monochromatic electron beams and quantum point contacts act as beam-splitters. In a Graphene PN junction, at high magnetic field, Mach-Zehnder like geometry is naturally achieved when two opposite chiral edge states co-propagate along the junction. It has been shown recently that depending on the Aharonov-Bohm phase between the two co-propagating modes the junction transmittance shows periodic oscillations. However, from the conductance measurement it is not possible to determine the details about the mixing mechanism. One of the most effective ways to unveil these microscopic details is the study of the partitioning noise (shot noise) generated by the co-propagating edges. Shot noise carries information about the energy distribution and subsequent partitioning of the carriers. Earlier shot noise studies on graphene PN junction have shown that the mode mixing happens either by quasi-elastic or inelastic scattering. For both the cases, the maximum Fano factor (F) was found to be ~0.25. It was also predicted that for coherent scattering process the Fano factor would be ~0.5, which is not seen till date. In this work we have studied high-quality graphene PN junction device having all the spin and valley symmetries broken. We have carried out detailed shot noise measurement on different combination of P side and N side quantum Hall plateaus. The analyzed Fano factor for most of the PN junction plateaus is always significantly greater than 0.25 and we observe systemic increment of Fano approaching ~ 0.5 with the more number of quantum Hall edges at the PN junction suggesting system is becoming fully coherent. The complete evolution of mode-mixing from de-coherence to fully coherent scattering at the graphene PN junction will pave the way to design the graphene based beam splitter for future interference experiments.
Abstract Title: Doping dependence of high-frequency Raman modes in twisted MoS2 bilayers

Electron phonon coupling (EPC) is emerging as a powerful tool to engineer the physical properties of 2D materials and their heterostructure. In this context understanding and manipulating the EPC in vertically stacked heterostructures of atomically thin van der Waals (vdW) crystals is critical for reproducible designing of devices with desired functionalities. Here, in the mechanically exfoliated twisted bilayer MoS2 (tBLMs), one of the simplest prototypes of vdw heterostructures, we show that the EPC and interlayer coupling can be strongly modified by the periodic potentials of Moiré patterns. Performing Raman spectroscopy on tBLMs of various twist angles having field effect transistor (FET) geometry, we demonstrate softening and broadening of A1g phonon the mode with electron doping, whereas other Raman active E2g mode remains inert. We show that EPC in the tBLMs with higher and lower twist angles is comparable to that in single layer MoS2 and high symmetry bilayer MoS2 (2H structure), respectively. Our results opens up new possibilities in twist angle dependent engineering of EPC and phonon modes in vdW heterostructures.

Name: Amartya Saha
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Abstract Title: Translation symmetry broken ground states near quantum hall edge at v=2
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Abstract Title: Is a one dimensional Fermi gas with spin-orbit coupling, Zeeman field, and intrinsic attractive interactions, truly topological?

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Searching for Majorana fermion excitations in condensed matter systems has recently emerged as a very active field of research, although experimental uncertainties still remain. The topological superfluid (TS) phase of a cold Fermi gas is also expected to host edge modes, which in one dimension (1D) can manifest into Majorana zero energy modes (MZMs) with an associated exponential topological degeneracy. It has been proposed recently that a numberconserving 1D Fermi gas can exhibit such topological degeneracy in the presence of spin-orbit coupling (SOC), Zeeman field, and attractive on-site Hubbard interactions, upon application of an external parabolic potential that arises naturally in ultracold atom systems confined by a harmonic trap potential. We have used density matrix renormalization group (DMRG) numerical technique to explore the phases that emerge from the interplay of SOC and Zeeman field in such a trapped 1D Fermi gas. To verify the existence of any topological phase, and its robustness in this set-up, we have calculated the lowest excitation energy gap, pair binding energy, expectation values of local operators, and the effect of local perturbations on this system.
find that, the apparent exponential degeneracy in the pair binding energy and spectral energy gaps notwithstanding, strictly speaking, the system is not in a topological phase due to susceptibility to local perturbations, and lack of local indistinguishability between the lowest lying states that are expected to be topologically degenerate. Thus, this system cannot be used for topological manipulation of quantum information.


Name: Shoubhik Mandal
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Abstract Title: Low Electrical Transport in Dual Topological Insulator BiTe
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We report the magneto-transport measurement of stable superlattice Bi1Te1, which has been recently proved to support(host) the co-existence of weak topological insulating state and topological crystalline insulating phase(dual topological insulator) by spin- and angle- resolved photoemission spectroscopy. In addition, very recently BiTe has been predicted to be higher order topological insulator (HOTI) which can also host topologically protected hinge states. The nature of topological surface states(SS) in “strong topological insulator” (STI) is experimentally confirmed by various electrical transport measurement and the results are in accord with theoretical predictions. But weak TI has so far eluded experimental verification, since the surface states emerge only on the particular sides. And the SS of topological crystalline insulator on the particular surfaces based on symmetry have been detected vaguely by electrical transport, rather than verified by ARPES. But, Bi1Te1, being a dual TI is a unique platform to study the electrical signature of topological SS of two fundamentally different origins. Though resistivity vs temperature proved metallic character of our as-grown single crystal Bi1Te1, the weak anti-localization present in perpendicular field transport data supports the presence of multiple topologically protected SS. Lψv T-p curve fitting yielded p=0.5 owing to 2D nature of our system. In addition, parallel field transport confirms the transport is in Altshuler- Aronov regime where thickness of the flake >> mean free path of carriers present in the system.

Name: Saurav Islam
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Abstract Title: Electrical characteristics of Ag/Au nanostructures
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The resistive and magnetic properties of silver/gold nanostructures under ambient conditions have generated significant debate and discourse1. Here, we report the electrical characteristics of such films, showing a resistive transition with a transition temperature $T_{\text{cas}}$ high as 286 K. The transition of resistance (R) to ~ few $\mu$Ω below $T_{\text{cis}}$ accompanied by the emergence of diamagnetism in the samples. The current-voltage(I-V) characteristics recorded through such transitions demonstrate a series of stairs-like features and hysteresis, which are consistent with previous reports of resistive transition through the formation of phase-slips centers in ultra-thin superconductors2.
Name: Arijit Dutta
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Abstract Title: The voltage driven Mott insulator at finite temperature
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We had developed a zero temperature real space mean field scheme for studying the steady-state nonequilibrium response of a Mott insulator driven by an external bias applied via coupling of metallic leads at the edges. We, now, extend this formalism to include thermal fluctuations of the local moments which allows us to study the fate of the Neel temperature and the insulator to metal transition temperature with bias voltage. It also gives us access to the temperature dependence of local density of states and the non-linear current-voltage characteristics of the system, which can be compared with experiments. More importantly, it leads to the possibility of finding new "phases" which do not exist in equilibrium.

Name: Jadupati Nag
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Abstract Title: Magnetic and transport behaviour in Co rich CoFeMnSi alloy
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In this work the effect of Co in the structural, electronic, magnetic and transport properties of spin gapless semiconductor (SGS) CoFeMnSi is investigated. SGS nature and improvement of bandgap have been predicted in these Co rich alloys by theoretical calculations. SGSs are the materials having a band structure in which one spin polarized subband resembles that of a semiconductor i.e. a finite band gap for one of the spin channel, while a closed gap for the other channel i.e. the other subband has a zero band gap at the Fermi level. Therefore, they can be thought of as a combination of a half metallic ferromagnet and a gapless semiconductor(GS). The alloys Co1+xFeMn1-xSi (x = 0.125 and 0.5) are found to crystallize in cubic Heusler structure with LiMgPdSn prototype having space group F43m (# 216) with a lattice parameter of 5.6A with both the superlattice re ection peaks (111) and (200) present in the XRD pattern. The saturation magnetization is found to match well with the value predicted by the Slater-Pauling rule. The ferromagnetic ordering temperature for all the alloys is found to be above room temperature. Electrical transport measurements show a mixture of semiconducting and metallic behaviour for x = 0.125 and metallic behavior for x = 0.5. High Curie temperatures (TC) and tunable electronic and magnetic properties make these alloys potential candidates for spintronics applications.

Name: Debarghya Mallik
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Abstract Title: Quantum oscillations and Non trivial Berry phase in a p-type topological insulator Sb1.99 Sn0.01 Te2 Se1
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Topological insulator hosting a plethora of intriguing phenomena (suppression of back scattering, Majorana fermion at TI-superconductor interface and so on) is a unique phase of matter showing insulating at the bulk and metallicity at the surface. Here in this report we show the magnetoresistance and the quantum oscillation (Shubnikov-de Haas oscillation) study of an exfoliated microflake from a single crystal of a topological insulator Sb1.99 Sn0.01 Te2 Se1. Quantum oscillations which is the consequence of the Landau quantization of the Fermi surface, allows us to plot the Landau fan diagram yielding the non-trivial \( \pi \)-Berry phase (a geometrical quantum phase) of the conducting electrons in our sample. From Lifshitz-Kosevich analysis of the oscillations we found out the effective mass of the electrons to be 0.14 times the rest mass of the electron and the dingle temperature to be 8.5 K. Resistance vs temperature plot shows the metallicity of the sample and the Hall data indicates that the carriers are hole type. Moreover we show the comparison of the mobilities and carrier concentration values extracted from the SdH oscillations analysis and the Hall data. Thus, our work demonstrates the Dirac nature of the electrons in our sample.
We study the effect of introducing a vortex in a second order topological superconductor and show that the vortex periodicity changes from \( h_0 = \frac{hc}{e} \) to \( h_0 = \frac{hc}{2e} \) as the corner Majorana states, which are the signatures of the topological superconducting state, mix with the bulk states leading to a crossover to an ordinary superconductor. The measurement of this change of periodicity would be a direct confirmation of the topology change and indirectly of the corner Majorana modes. We also show that the change of periodicity can be tuned by shining light on the superconductor.

Coulomb drag is the ultimate tool for studying electron-electron interaction in mesoscopic systems. It was first observed between 2D and 3D electron gas layers of AlGaAs/GaAs system [1]. Since then drag measurement has been performed on numerous 2D-2D systems [2], 1D-1D system [3] as well as hybrid structures to investigate the charge in-homogeneity, charge fluctuation, correlation physics etc. Drag in 2D-2D systems are mostly explained by the standard momentum transfer mechanism where the system is considered to be in Fermi liquid regime. Drag for 1D-1D systems are particularly interesting as the electron interactions are stronger compared to the 2D systems and often described by Tomonaga-luttinger liquid theory. However, the coulomb drag has not been explored in 2D-1D hybrids. Here, we have carried out the drag measurement between 2D monolayer (SLG)/bilayer graphene (BLG) and 1D InAs nanowire (NW) heterostructures. In the drag measurement a known current has been driven through one of the layer and the open circuit voltage is measured in the other layer. For most part of the experiment a fixed density of the NW is maintained and the drag voltage is measured at different densities of the graphene by varying the back gate voltage. For SLG-NW devices the drag voltage peaks at the Dirac point, whereas for BLG-NW devices the drag signal changes sign across the Dirac point. These results suggest that the homogeneous and in-homogeneous momentum drag dominate in BLG-NW and SLG-NW devices, respectively. Moreover, for SLG devices the drag signal is highly sensitive to magnetic field, but in BLG based devices it is almost invariant. However, both types of devices show anomalous temperature dependence where drag signal decreases with increasing temperature contrary to momentum drag signature of dependence. In conclusion, this kind of drag study aids the understanding of electron-electron correlation in 2D-1D heterostructures which in future will help us to realise excitonic condensate in diverse systems.

In a type-II superconductor, magnetic field gets penetrated through vortices, called Abrikosov vortices. These vortices arrange themselves in a spatial periodic manner forming a vortex lattice. The magnetic field coming out of this vortex lattice can be used to produce a periodic magnetic field over a closely placed two-dimensional electron gas (2DEG). Several exciting effects on 2-DEG arising from periodic magnetic field have been predicted theoretically, e.g., generation and manipulation of anyons [1], quantization of the anomalous Hall effect [2], spin/charge textures [3], gap opening at Dirac points [4], and development of magnetic minibands [5]. Here we try to investigate the effect of periodic magnetic field on graphene transport properties kept in proximity of single crystalline NbSe2 thin flake. In vortex state of NbSe2, suppression of Hall conductance in graphene is observed, indicating that measured Hall conductance value is lower than value as it would have been for a uniform magnetic field. Although the effect of periodic magnetic field is not observed in our present data. In future, we are aiming to fabricate high quality devices to observe effect of magnetic lattice of vortices.
In this work, the powerful Non-chiral bosonization technique (NCBT) is introduced, which is a non-trivial modification of the standard Fermi-Bose correspondence in one spatial dimension made in order to facilitate the study of strongly inhomogeneous Luttinger liquids (LL) where the properties of free fermions plus the source of inhomogeneities are reproduced exactly. The formalism is applied to obtain the correlation functions of translationally non-invariant systems like LL with a cluster of impurities (barriers/wells) around an origin, a one-step fermionic ladder, slowly moving impurities in a Luttinger liquid, etc. The obtained correlation functions are used to study various physical phenomena like Friedel oscillations, resonant tunnelling, dynamical density of states, conductance, mobility (in case of mobile impurities) and so on. The results are validated using the Schwinger Dyson equation and perturbative methods. The present method is superior to the conventional bosonization methods (g-ology methods) which requires additional tools like re-normalization, etc. to deal with impurities.


What is the fate of a many-body localized system under a voltage bias between two ends? Can the system undergo a transition to a current carrying non-equilibrium steady state and how the entanglement properties of the quantum states change across the transition? Motivated by these questions, we model a current driven interacting disorder system through a non-Hermitian Hamiltonian and study the entanglement properties of its eigenstates. We also discuss the dynamics, entanglement Hamiltonian and long-time fate of a generic initial state under an appropriate time-evolution of the system governed by the non-Hermitian Hamiltonian. Our study reveals rich entanglement structures of current driven states and multiple dynamical transitions as a function of disorder and the strength of the non-Hermitian term, that is related to the external bias.
Our studies reveal the coexistence of geometric magnetic frustration and orthorhombic structural distortions, where distortion-driven multiferroic order occurs as a result of release of magnetic frustration in CaBaCo4O7. The control of Ca doping by La is investigated on Ca1−xLaxBaCo4O7 (x ≤ 0.05). Structural studies reveal that La doping increases considerable structural distortion, which is associated with the increase of multiferroic ordering temperature and electric polarization. Interestingly, the value of polarization increases remarkably to ≈385 μC/m2 (x = 0.05) from ≈150 μC/m2(x = 0) for a 3 kV/cm applying of poling field. Synchrotron diffraction studies in magnetic field provides an important evidence, where structural distortion provides more impact on the polarization value than the contribution from the change in unit cell volume. Geometric magnetic frustration holds the key for the occurrence of the structural distortions, around which multiferroic ordering takes place for CaBaCo4O7. Our work thus highlights crystal structural distortion as a rich playground for tuning multiferroic order as well as polarization value.


Orbital selective Mott physics is believed to play an important role in a number of iron-based superconductors like FeSe, in charge order transitions in bilayer Ruthenate and potentially in superconducting state of Strontium Ruthenate. Recent advances in strain engineering such compounds have allowed an additional tuning parameter to study emergent properties in these materials. In this work I will take the example of the well-known compound VO2 and show that application of uniaxial strain along different crystallographic directions provides a method to tune the orbital selective Mott physics of compounds that are close to metal insulator transitions. We perform a combined DFT and U(1) slave spin calculation and confirm the results using experiments such as HAXPES to show that strain can enhance or suppress electron correlations in certain electronic bands.

The specific topology of the lattice has a strong influence on the overall spectrum and in certain cases it can induce exotic spectral features through a set of macroscopically degenerate dispersionless flat bands. The momentum independence of the single particle eigenstates brings the flavor of divergent effective mass leading to the immobility of the incoming excitation. The extremely low group velocity of the wave packet causes a singularity in the density of states. This divergence plays a crucial role in the context of thermoelectric devices to enhance their thermopower and forming low-threshold laser device. The methodology to discern the flat band modes in some quasi-one dimensional networks is reported within the tight-binding framework following the real space renormalization group (RSRG) scheme. Analytical calculations regarding the decoupling scheme to demonstrate the localizing character of those non-dispersive states have been reported. Dispersion relation and two-terminal transport of those systems have been worked out using the RSRG method. Tight-binding analogy
provides a smooth platform to map our electronic problem onto the corresponding photonic scenario. The analytical technique of this one-to-one mapping is discussed elaborately. In the context of photonic flat band modes, concept of slow light is also introduced. Slow light is a very promising solution for optical delay line or optical buffering and advanced time-domain optical signal processing. It is also anticipated to enhance linear and nonlinear effects and so miniaturize functional photonic devices, as slow light compresses optical energy in space that eventually increases the light-matter interaction.

Name: Upendra Kumar
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Abstract Title: Inducing half metallicity with alloying in Heusler Compound CoFeMnSb
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First principles studies were performed in order to find out the possibility of inducing half-metallicity in Heusler Compound CoFeMnSb, by means of alloying it with 3d-transition metal elements. Proper alloying element is selected through the calculations of formation energies. These calculations were tested with different concentrations of alloying elements at different atomic sites. Among the selected transition metal elements Sc and Ti are proposed to be excellent alloying elements, particularly at Mn site. By using these alloying elements complete half metallic behaviour is obtained in CoFeMn0:25Sc0:75Sb, CoFeMn0:75Ti0:25Sb, CoFeMn0:625Ti0:375Sb, CoFeMn0:50Ti0:50Sb, CoFeMn0:25Ti0:75Sb and CoFeTiSb alloys. Shifting of Co-Fe d-states towards lower energy region leads to zero density of states at Fermi level for the spin minority channel. Alloying effects on the electronic structure and magnetization are discussed in details. Thermodynamical stability of these new alloys is a major part of this study. The Curie temperatures of CoFeMn0:25Sc0:75Sb and CoFeMn0:75Ti0:25Sb were found to be 324.5 K and 682 K; respectively, showing good candidature for spintronics applications. For understanding the bonding nature of the constituent atom of CoFeMnSb, crystal orbital Hamiltonian populations have been analysed.

Name: Sanjukta Paul
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Abstract Title: Multi orbital Hubbard model at finite temperatures: A Monte-Carlo-Mean field study
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The multi-orbital Hubbard model is of relevance for most strongly correlated materials. As such the many body complexity and multiple local degrees of freedom makes calculation of such models almost intractable by exact methods. Also, traditional methods like Determinantal Monte-Carlo suffer from enhanced fermion sign problem in the multi orbital case. Thus, a reliable approximation that allows solving the multi orbital problem is of paramount importance. In this talk we will discuss the Mean-Field-Monte-Carlo (MF-MC) method and its application to two and three orbital Hubbard model. We will present the finite temperature phase diagrams when all interactions are retained (within the Kanamori representation). By choosing hopping elements and lattice geometry relevant to the undoped Iron based superconductor materials, we will show the interplay of magnetism and nematicity, discuss metal insulator transitions and present results on orbital selective Mott transitions.

Name: Panch Ram
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Abstract Title: Inversion and Magnetic Quantum Oscillations in Symmetric Periodic Anderson Model
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We study the symmetric periodic Anderson model [1] of the conduction electrons hybridized with the localized correlated electrons on square lattice. Using the canonical representation of electrons by Kumar [2, 3], we do a self-consistent theory of its effective charge and spin dynamics, which produces an insulating ground state that
undergoes continuous transition from the Kondo singlet to Néel antiferromagnetic phase with decreasing hybridization, and uncovers two inversion transitions for the charge quasiparticles. With suitably inverted quasiparticle bands for moderate to weaker effective Kondo couplings, this effective charge dynamics in the magnetic field coupled to electronic motion produces magnetic quantum oscillations with frequency corresponding to the half Brillouin zone [4].

References:

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Abstract Title: A Kitaev liquid, under strain
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Condensed matter physics provides a fascinating playground to investigate and explore ideas and phenomena where emergence, topology and fractionalization interplay. Moreover, magnetic materials and their odd properties often become test beds for such interesting physics. In this talk, I will illustrate our recent investigations on the effect of strain on a Kitaev magnet. In particular I will show how ideas from quantum Hall, of fractionalization in magnets, and even SYK like physics combine in this unique setting (showing an emergence of a distinct phase of matter. Time permitting, I will discuss the experimental scope of this study.

Name: Subhamoy Ghatak
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Abstract Title: Observation of anomalous Fraunhofer patterns in Al-BiSbTeSe2-Josephson junctions
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Three dimensional topological insulators (3D-TIs) have recently drawn a considerable interest due to their spin-helical surface band structure. The Josephson junctions made of these 3D-TIs, by proximitizing with s-wave superconductors, are predicted to harbour 1D- Majorana modes. While observations of supercurrent in 3D-TI-based Josephson junctions are recently reported, the Fraunhofer patterns observed in such topological Josephson junctions, which sometimes present anomalous features, are still not well understood. In this talk, I will discuss about our study on highly gate-tunable topological Josephson junctions made of one of the most bulk-insulating TI materials, BiSbTeS2, and Aluminium (Al). The Fermi level can be tuned by gating across the Dirac point, and the high transparency of the Al/BiSbTeSe2 interface is evinced by a high characteristic voltage and multiple Andreev reflections with peak indices reaching n = 12. Anomalous Fraunhofer patterns with missing lobes were observed in the entire range of gate voltage. We find that, by employing an advanced fitting procedure to use the maximum entropy method in a Monte Carlo algorithm, the anomalous Fraunhofer patterns can be explained as a result of inhomogeneous supercurrent distributions on the TI surface in the junction. At the end, I will also discuss about our recent progress on graphen-based Josephson junctions which hold arealizable promise to implement them as future qubit devices.
Chaos, the sensitivity to the initial condition, lies at the foundation of statistical mechanics. Chaotic systems are characterized by a growth rate, the Lyapunov exponent $\lambda$, and a velocity for ballistic spread, the buttery velocity $v_b$, of local perturbation. Here we study the temperature dependence of the chaotic behavior across thermal phase transitions in a well-known classical spin system, the XXZ model on a square lattice. We tune the finite-temperature phase transition from the Kosterlitz-Thouless (KT) to Ising universality class by changing the anisotropy and find the temperature ($T$) dependence of $\lambda$, $v_b$, and the diffusion coefficient $D$ across these transitions. For both the KT and Ising cases, we find a crossover in $\lambda(T)$. On the contrary, $v_b(T)$ displays a non-monotonic temperature dependence across the transitions. We also find intermediate-time super-ballistic spreading of the initial perturbation in the low-temperature phases.