Subroto Mukerjee -
Boosted 1D superfluids :

We study the effect of a boost (that engenders a current-carrying state) on one dimensional systems of lattice fermions with short-ranged attractive interactions. In the absence of a boost such systems possess algebraic superconducting order. Naively, one might expect a boost to weaken and ultimately destroy superconductivity, as in higher dimensions. However, we show that for one dimensional systems its effect is to {\em strengthen} the algebraic superconducting order by making correlation functions fall off more slowly with distance. In the presence of a lattice, when umklapp is operative, the boost can open or close a gap depending on whether the fermions are spinless or possess spin. We explain the physical underpinnings of these findings.

Arnab Sen -
Dynamics of entanglement generation in driven integrable systems :

It has only been recently found that periodically driven closed quantum systems can have steady states that may be described by thermodynamical ensembles even though energy is not a conserved quantity. Here, we consider the system's approach to the steady state for periodically driven integrable spin systems such as the transverse field Ising chain and the Kitaev model. We unravel a novel dynamic transition in the relaxation to the steady state and relate it to the change in topology of the Floquet spectrum of such systems. These dynamical phases show a rich re-entrant behaviour as a function of the driving frequency in 1D (and for a class of 2D models) and we discuss experiments that can test our theory. We further show that such drives may lead to the controlled generation of pure states with non area and non-volume law entanglement entropy.

Yogesh Singh -
Realization of a quantum spin liquid based on a novel frustration mechanism :

Unlike conventional magnets where the magnetic moments are partially or completely static in the ground state, in a quantum spin liquid they remain in collective motion down to the lowest temperatures. The importance of this state is that it is coherent and highly entangled without breaking local symmetries. In the case of magnets with isotropic interactions, spin liquid behavior is sought in simple lattices with antiferromagnetic interactions that favour antiparallel alignments of the magnetic moments and are incompatible with the lattice geometries. Despite an extensive search experimental realizations remain very few. We will introduce the novel, unexplored magnet Ca10Cr7O28 which has a complex Hamiltonian consisting of several different isotropic interactions and where the ferromagnetic couplings are stronger than the antiferromagnetic ones. We show both experimentally and theoretically that it displays all the features expected of a quantum spin liquid. Thus spin liquid behavior in isotropic magnets is not restricted to the simple idealized models currently investigated but can be compatible with complex structures and ferromagnetic interactions.

Jurgen Smet -
Fractional quantum Hall states in bilayer graphene probed by transconductance fluctuations :

We have investigated fractional quantum Hall states in Bernal-stacked bilayer graphene using transconductance fluctuation measurements [1]. A variety of odd-denominator fractional states with v QH →v QH + 2 symmetry, as previously reported in the literature, are observed. However, surprising is that also particle-hole symmetric states are clearly resolved in the same measurement set. We attribute their emergence to the reversal of orbital states in the octet level scheme induced by a strong local charge imbalance, which can be captured by the transconductance fluctuations. Also the even-denominator fractional QH state at filling −1/2 is observed. Contrary to a previous study on a suspended graphene layer [2], the particle-hole symmetric state at filling 1/2 is detected as well. These observations suggest that the stability of both odd and even denominator fractional QH states is very sensitive to local transverse electric fields in bilayer graphene.

[1] Y. Kim, D.-S. Lee, S. Jung, V. Skákalová, T. Taniguchi, K. Watanabe, J.S. Kim, J.H. Smet, Nano Lett.15, 7445 (2015).
[2] D.-K. Ki, V.I. Fal´ko, D.A. Abanin, A. Morpurgo, Nano Lett. 14, 2135 (2014).

Shunsuke Furukawa -
Magnetic properties of volborthite determined by a coupled-trimer model :

The natural mineral volborthite hosts layers of spin-1/2 moments forming a kagome lattice. While this material was initially considered as a candidate of a spin-1/2 kagome antiferromagnet, it exhibits rich magnetic behavior which is in many respects distinct from the known features of a kagome antiferromagnet. In particular, recent single-crystal experiments have revealed a wide 1/3 magnetization plateau starting at H=26 T, an incommensurate spin-density-wave phase below H=23 T, and the novel "N" phase in between them. To explain these rich field-induced phenomena, we have performed microscopic modeling of volborthite by means of density functional theory (DFT) with the single-crystal structural data as a starting point. Using DFT+U, we find four leading magnetic exchanges: antiferromagnetic J and J_2, as well as ferromagnetic J' and J_1 with a remarkable hierarchy $J>|J_1|>J_2,|J'|$. Due to the dominance of J, the magnetic planes break up into magnetic trimers. The 1/3-plateau state can be naturally interpreted as a product of polarized trimers, and a wide plateau extending to H=225 T is predicted. Furthermore, we derive an effective pseudospin-1/2 model by restricting ourselves to the lowest-energy doublet on each trimer and treating the inter-trimer couplings perturbatively. This model shows a tendency towards condensation of magnon bound states preceding the plateau, providing a scenario for the observed "N" phase. Reference: O. Janson, S. Furukawa, T. Momoi, P. Sindzingre, J. Richter, and K. Held, arXiv: 1509.07333.

Mandar M. Deshmukh -
Quantum Hall ferromagnetism in trilayer graphene :

We discuss quantum Hall measurements on a high quality encapsulated tri-layer graphene device. Low temperature field effect mobility of this device is around 500,000 cm^2/Vs and we see SdH oscillations at a magnetic field as low as 0.3 T. Quantum Hall measurements confirm that the chosen tri layer graphene is Bernal (ABA) stacked. Due to the presence of both mass-less monolayer like Dirac fermions and massive bi-layer like Dirac fermions in Bernal stacked tri-layer graphene, there are Landau level crossings between monolayer and bi-layer bands in quantum Hall regime. We observe a series of crossings of the spin and valley resolved Landau Levels. The regions of LL crossings result in quantum Hall ferromagnetic states as exchange interaction becomes the dominant energy scale.

Takashi Oka -
Control of Topology in Quantum Materials by Laser :

The effect of strong laser on the topology of many body systems is becoming a hot topic [1,2,3]. A theoretical proposal was made in two dimensional Dirac systems where an application of circularly polarized light was shown to turn the system into a quantum Hall state [1,2]. One can see this as a dynamical realization of the Haldane model of a quantum Hall state without Landau levels [4]. This effect can be understood with the help of the Floquet theory for driven quantum systems, where the circularly polarized light plays the role similar to the “next nearest hopping with a nontrivial phase factor” in the Haldane model. Floquet theory can be applied to other many-body systems as well. We have been studying the effect of laser on quantum magnets, multiferroics, and two dimensional gas [5]. In my talk, I will report our recent progresses.

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[2] T. Kitagawa, T. Oka, A. Brataas, L. Fu, E. Demler, Phys. Rev. B 84, 235108 (2011).
[3] N. H. Lindner, G. Refael, V. Galitski, Nat. Phys. 7 490 (2011).
[4] F. D. M. Haldane, Phys. Rev. Lett. 61 2015 (1988).
[5] T. Oka and L. Bucciantini, in prep.

Amit Ghosal -
Strong disorder in strongly correlated matter: Perspective from cuprates:

The effect of potential impurities on cuprate superconductors will be discussed using a formalism suitable for addressing the complex interplay of the bare repulsive electronic correlations and disorder, both being strong. We show that the mechanism governing the demise of superconductivity is rather subtle and differs from conventional descriptions. While the superconductivity remains surprisingly robust for up to a moderate disorder, it crashes down sharply at strong disorders. The initial robustness is attributed to the repulsive correlations that smear out charge inhomogeneities by self-consistently reorganizing the hopping on the bonds.

Such reorganization prohibits the formation of superconducting “islands”. With increasing strength of disorder, however, the potential difference across some bonds reach of the order of bandwidth and the system prefers prohibiting hopping on such links. Integrating this concept within our formalism, we show that the correlations fail to homogenize the system across these “cut-bonds”. This produces locally Mott-insulating, Anderson-insulating, as well as superconducting regions interspersed among each other, eventually destroying the global superconductivity.

Subhasis Sinha -
Phases, collective modes and non-equilibrium dynamics of dissipative Rydberg atoms in an optical lattice :

We chart out the possible phases of laser driven Rydberg atoms in the presence of a hypercubic optical lattice. Analytical expressions of the phase boundaries and collective excitations are obtained in the hardcore limit. Next we use a density matrix formalism to study the equilibrium phases and non-equilibrium dynamics of a system of dissipative Rydberg atoms in an optical lattice within mean-field theory. We provide equations for the fixed points of the time evolution of the density matrix and analyze these equations to obtain the Mott insulator-superfluid (MI-SF) phase boundary. A stability analysis around these fixed points provides us with the excitation spectrum of the atoms both in the MI and SF phases. Finally we discuss the non-equilibrium dynamics of Rydberg atoms in presence of dissipation by varying the hopping parameter and dissipation strength.

Sudhansu Mandal -
Topological Structure and Almost Exact Ground State Wave Function: A New Light on Enigmatic 5/2 Fractional Quantum Hall State :

Moore-Read Pfaffian wave-function whose alternative description is a chiral p-wave paired state of composite fermions has been proposed as possible description of experimentally observed first even denominator fractional quantum Hall state at the filling factor 2+1/2, i.e., filling factor 1/2 in the second Landau level. This state can also be recasted as clustering of two different species of particles known as para-fermions. However, not only that the consequences of this proposal has not been completely realized by experiments, the exact coulomb ground state wave function is not very closed to the proposed wave function. This enigma remains an outstanding issue even after almost three decades of its first realization. In this talk, I will describe a comprehensive scheme for determining topological structure—order of zeros felt by an electron at the positions of other electrons-- -of the state and the resultant wave function can be found to be almost exact with any interaction that produces incompressible 5/2 state. We argue that the Coulmob ground state corresponds to the closeness of composite bosons up to half of the number of electrons, in contrary to the proposed Para-fermion wave function where only two composite bosons can come close together. We hope that the outstanding issues like whether or not the observed 5/2 state corresponding to realistic Coulomb interaction will have quasiparticle charge e/4 and the edge mode will support neutral Majorana will now be revealed.

Anindya Das -
Andreev reflection near the Dirac point at Graphene – NbSe 2 junction :

Despite extensive search for about a decade, specular Andreev reflection is only recently realized in bilayer graphene-superconductor interface. However, the evolution from the typical retro type Andreev reflection to the unique specular Andreev reflection in single layer graphene has not yet been observed. We investigate this transition by measuring the differential conductance at the van der Walls interface of single layer graphene and NbSe 2 superconductor. We find that the normalized conductance (G T<Tc /G T>Tc) becomes suppressed as we pass through the Dirac cone via tuning the Fermi level and bias energy, which manifests the transition from retro to non-retro type Andreev reflection. The suppression indicates the blockage of Andreev reflection beyond a critical angle (c) of the incident electron with respect to the normal between the single layer graphene and the superconductor junction. In the last part I will discuss about the Cooper pair tunneling into a quantum Hall edge state of graphene.

Ying-Jer Kao -
Field Induced Ordering in Dipolar Spin Ice :

We report numerical results of a dipolar spin ice in a magnetic field. First, by tuning the magnetic field along the [100] direction, the system exhibit a half-magnetization plateau at low temperature. This half-polarized phase should correspond to a quantum solid phase in an effective 2D quantum boson model, and the transition from the Coulomb phase with a power-law correlation to this state can be regarded as a superfluid to a quantum solid transition. On the other hand, in the presence of a magnetic field slightly tilted away from the [111] axis, we find a first-order transition from a kagome ice to a q =X state when the external field is tilted toward the [11-2] direction. This is consistent with the anomalous critical scattering previously observed in the neutron scattering experiment on the spin ice material Ho2Ti2O7 in a tilted field [Nat. Phys. 3, 566 (2007)]. We show that this ordering originates from the antiferromagnetic alignment of spin chains on the kagome planes. The residual entropy of the kagome ice is fully recovered. Our result captures the features observed in the experiments and points to the importance of the dipolar interaction in determining ordered states in the spin ice materials. We place our results in the context of recent susceptibility measurements on Dy2Ti2O7, showing two features for a [111] field.

R Ganesh -
Extended degeneracy and order by disorder in the square lattice J1-J2-J3 model :

The square lattice J1-J2 antiferromagnet continues to generate tremendous interest, with an elusive quantum disordered phase in the vicinity of J2 = J1/2. At this precise value of frustration, the classical model has a very large degeneracy which makes the problem difficult to handle.

We show that introducing a ferromagnetic J3 coupling partially lifts this degeneracy. It gives rise to a four-site magnetic unit cell with the constraint that the spins on every square must add to zero. This leads to a two-parameter family of ground states and an emergent vector order parameter. We reinterpret this family of ground states as coexistence states of three spirals. Using spin wave analysis, we show that thermal and quantum fluctuations break this degeneracy differently. Thermal fluctuations break it down to a threefold degeneracy with a N\'eel phase and two stripe phases. This threefold symmetry is restored via a Z3 thermal transition, as we demonstrate using classical Monte Carlo simulations. On the other hand, quantum fluctuations select the N\'eel state. In the extreme quantum limit of spin-1/2, we use exact diagonalisation to demonstrate N\'eel ordering beyond a critical J3 coupling. For weak J3, a variational approach suggests an s-wave plaquette-RVB state. Away from the J2 = J1/2 line, we show that quantum fluctuations favour N\'eel ordering strongly enough to stabilize it within the classical stripe region. Our results shed light on the origin of the quantum disordered phase in the J1-J2 model.

Amit Dutta -
Emergent topology in quenched quantum systems :

We study the real time evolution of a closed quantum system that is quenched or slowly ramped across quantum critical points. Corresponding non-analyticties in the rate function of the return probability occurring at different instants of time are referred to as dynamical phase transitions. We show, focusing especially on the slow ramping case, the emergence of a topological order parameter that exhibits a distinct jump of unit magnitude marking each dynamical transition.

Jainendra Jain -
Fractional quantum Hall effect in a spin :

In general, fractional quantum Hall states with different spin polarizations can occur at a given filling factor, and transitions between them can be induced by varying the Zeeman energy. The critical Zeeman energies are a direct measure of the differences between the interaction energies of the differently spin polarized states, and thus serve as an extremely sensitive test of the quantitative accuracy of a theory. I will report on our work [1] comparing the composite fermion theory with experiments, and also discuss how the study of spin transitions can teach us about the degree of breaking of the particle-hole symmetry due to Landau level mixing.

[1] Yuhe Zhang, Arkadiusz Wojs, J. K. Jain, preprint (2016)

Vikram Tripathi -
A non-Hermitian Hamiltonian description of the dynamic Mott transition :

We describe the critical behavior of the electric field-driven (dynamic) Mott insulator-to-metal transitions in dissipative Fermi and Bose systems in terms of non-Hermitian Hamiltonians invariant under simultaneous parity (P) and time-reversal (T) operations. The dynamic Mott transition is identified as a PT symmetry-breaking phase transition, with the Mott insulating state corresponding to the regime of unbroken PT symmetry with a real energy spectrum. We establish that the imaginary part of the Hamiltonian arises from the combined effects of the driving field and inherent dissipation. We derive the renormalization and collapse of the Mott gap at the dielectric breakdown and describe the resulting critical behavior of transport characteristics. The obtained critical exponent is in an excellent agreement with experimental findings on nanopatterned superconducting proximity arrays.

Goutam Sheet -
Tip-Induced superconductivity at mesoscopic point contacts on topologically nontrivial materials :

I will talk about the emergence of (tip-induced) local superconductivity at mesoscopic interfaces between sharp tips of elemental normal metals and certain (non-superconducting) materials with topologically nontrivial band structures. The list of materials on which we have detected a tip-induced superconducting phase includes a 3D Dirac semimetal Cd3As2 Bi2Te3 and a topological crystalline insulator Pb0.6Sn0.4Te. Several spectroscopic information from such local superconducting phases existing only under point contacts can be extracted by Andreev reflection spectroscopy. Such measurements on the materials mentioned above show that in most of the cases the tip induced superconducting phases are unconventional in nature. When the normal metallic tips are replaced by tips made out of conventional superconductors, features associated with multiple Andreev reflection are also observed. In addition, strong zero-bias conductance peaks (ZBCP) appear in the point contacts formed in ballistic regime of transport possibly indicating the presence of zero energy Andreev bound states due to the unconventional nature of the order parameter. At the end I will also present the evidence of highly spin-polarized surface current and large anisotropic magnetoresistance on single crystals of the strong spin-orbit coupling semiconductor Sb2Se3 which is known to be a trivial band insulator, a topological insulator.

Kedar Damle -
Vacancy-induced local moments in frustrated magnets :

Substitutional vacancies (non-magnetic ions that replace some of the magnetic moments of an insulating magnet) can dominate the low temperature susceptibility of frustrated magnets merely by creating isolated spins or paramagnetic clusters. Apart from this easy-to-understand effect, vacancies can also lead to more nontrivial phenomena that can serve as signatures of the low-energy physics of frustrated magnets. I will briefly survey some examples along these lines, drawing from our own recent work.

Arindam Ghosh -
Experimental access to backscattering-free modes of electron transport in graphene :

I shall describe some of our recent experiments on specially fabricated devices of graphene, where we attempted to investigate nontrivial channels of charge transport. In particular, our goal has been to access the propagating modes in graphene (single/bi and few layers) along the zigzag edge, which are known to host non-dissipative one dimensional transport modes. These modes are also expected to be strongly modified by electron-electron interaction. Experimental access to these modes has been rare due to intrinsic difficulty in fabricating graphene nanostructures with high-quality edges. I shall describe how we achieve this in our experiments, and present some recent transport data that indicates possibility of edge-bound transport in graphene nanostructures.

Daniel Podolsky -
Buckling transitions and clock order of two-dimensional Coulomb crystals :

Crystals of repulsively interacting ions undergo a buckling instability towards a multi-layer structure as the transverse trap frequency is reduced. I will show that the effects of thermal and quantum fluctuations can be understood by mapping this structural instability to the six-state clock model. A prominent implication of this mapping is that at finite temperature, fluctuations split the buckling instability into two thermal transitions, accompanied by the appearance of an intermediate phase with power-law correlations. As the confining potential is increased, the thermal transitions merge into a single quantum critical point. Within the ordered phase there is a crossover from classical to quantum behavior, signifying the emergence of an additional characteristic scale for clock order. I will discuss experimental realizations with trapped ions and polarized dipolar gases.

Diptiman Sen -
Observation of a macroscopic topological insulator phase in an assembly of coupled topological insulator nanocrystals :

We show that a granular thin film of Bi_2 Se_3 can behave like a single topological insulator crystal. Electrical transport experiments show clear signatures of topological surface states despite the granularity; however this system has distinctly different properties from conventional bulk TI systems including surface state coupling-decoupling transitions, large surface state penetration depths and exotic Berry phase effects. We present a model which explains these results. Our findings illustrate that granularity can be used to engineer TIs, at the same time allowing easy access to physics which is difficult to observe in single crystal systems.

A. Banerjee, O. Deb, K. Majhi, R. Ganesan, D. Sen and P. S. Anil Kumar,
arXiv:1604.03767

Pavan Hosur -
Time-reversal asymmetry without local moments via directional scalar spin chirality :

Invariably, time-reversal symmetry (TRS) violation in a state of matter is identified with static magnetism in it. Here, a directional scalar spin chiral order (DSSCO) phase is introduced that disobeys this basic principle: it breaks TRS but has no density of static moments. It can be obtained by melting the spin moments in a magnetically ordered phase but retaining residual broken TRS. Orbital moments are then precluded by the spatial symmetries of the spin rotation symmetric state. It can exist in one, two and three dimensions under different conditions of temperature and disorder. Recently, polar Kerr effect experiments in the mysterious pseudogap phase of the underdoped cuprates hinted at a strange form of broken TRS below a temperature TK, that exhibits a hysteretic "memory effect" above TK and begs reconciliation with nuclear magnetic resonance (which sees no moments), X-ray diffraction (which finds charge ordering tendencies) and the Nernst effect (which detects nematicity). Remarkably, the DSSCO provides a phenomenological route for reconciling all these observations, and it is conceivable that it onsets at the pseudogap temperature ~T∗. A testable prediction of the existence of the DSSCO in the cuprates is a Kerr signal above TK triggered and trainable by a current driven along one of the in-plane axes, but not by a current along the other.

Pratap Raychaudhuri -
Melting of the vortex lattice in a Type II superconductor: A story from images :

In the vortex state of a Type II superconductor, magnetic flux lines arrange themselves through mutual repulsive interactions to form a soft periodic solid. This system has long been used as a versatile model system to study the interplay between interaction and random pinning. Here, I will present real space images of the vortex lattice as it melts with temperature or magnetic field, acquired using the low temperature, high field scanning tunneling microscope built in our laboratory. These images reveal that the presence of a random pinning potential fundamentally alters the order-disorder transition, and gives rise to a variety of metastable states that can be accessed through thermomagnetic cycling.

Refs:
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2) Somesh Chandra Ganguli, Harkirat Singh, Rini Ganguly, Vivas Bagwe, Arumugam Thamizhavel and Pratap Raychaudhuri, J. Phys.: Condens. Matter **28,** 165701 (2016).
3) Somesh Chandra Ganguli, Harkirat Singh, Garima Saraswat, Rini Ganguly, Vivas Bagwe, Parasharam Shirage, Arumugam Thamizhavel &Pratap Raychaudhuri Scientific Reports 5, 10613 (2015).

Lloyd Engel -
Microwave studies of Wigner solids in Bilayer systems :

In high magnetic fields, 2D or bilayer Wigner solids hosted in semiconductor exhibit resonances in their rf or microwave conductivity. The resonances are understood as pinning modes, collective oscillations of pieces of the solid about their disorder-pinned positions. Such solids occur at the low Landau filling () termination of the series of quantum Hall effect states. I will discuss the low- solids in two different types of bilayer systems.
The first system is a wide single quantum well, which is in a bilayer state when the Coulomb energy sufficiently exceeds the gap between first and second subbands. This system shows multiple bilayer solid phases, with solid-solid transitions that can be observed from the pinning mode. The system also presents a Wigner solid of quasiholes of the ½ fractional quantum Hall state; such quasiholes would expected to have dipolar charge distribution at least in the dilute limit.
The second bilayer system is a double well with one layer at much lower density than the other. The majority layer is in the regime of the fractional quantum Hall effects; the minority layer is in the Wigner solid state and exhibits a pinning mode. The majority layer state appears to have an effect on the charge density participating in the pinning mode oscillations.

Subir Sachdev -
Quantum matter without quasiparticles: random fermion models, black holes and graphene :

A central characteristic of quantum matter without quasiparticles is that it has the shortest possible local equilibration time of order Planck’s constant divided by the absolute temperature. Recently, this fast equilibration has been linked to many-body quantum chaos, also exhibited by black holes. I will describe the solution of the Sachdev-Ye-Kitaev (SYK) random fermion models, whose properties match those of those extremal black holes, and which saturate the lower bound on the Lyapunov time to quantum chaos. These ideas have also influenced predictions of transport in graphene, which agree well with recent observations.