Abstracts of Invited Talks

Ian Affleck UBC, Vancouver
Phase Diagram of a Chain of Interacting Majorana Fermions
While the interacting Dirac fermion chain is well understood, the chain of Majorana (Hermitean) fermion operators has recently been proposed as an experimentally realizable model. I will discuss its fascinating phase diagram which includes the supersymmetric tri-critical Ising point and a generalized commensurate-incommensurate transition.

Eric Akkerman Technion University
Observing a Scale Anomaly in Graphene: a Universal Quantum Phase Transition
Scale invariance is a common property of our everyday environment. Its breaking gives rise to less common but beautiful structures like fractals. At the quantum level, breaking of continuous scale invariance is a remarkable example of quantum phase transition also known as scale anomaly. The general features of this transition will be presented at an elementary quantum mechanics level. Then, we will show recent experimental evidence of this transition in graphene.

Natan Andrei Rutgers University
Quantum Impurity in Luttinger Liquid – Exact solution of the Kane-Fisher model and beyond
A Luttinger Liquid coupled to quantum impurity describes a large number of physical systems. The Hamiltonian consists of left- and right-moving fermions interacting among themselves via a density-density coupling and scattering off a transmitting and reflecting impurity which may be a local potential or a quantum dot. I will present an exact solution of the Hamiltonian(s) by means of an incoming-outgoing scattering Bethe basis which properly incorporates all scattering processes. The consistency of the construction is established through a generalized Yang-Baxter relation. Periodic boundary conditions are imposed and the resulting Bethe Ansatz equations are derived by means of the Off Diagonal Bethe Ansatz approach. We derive the spectrum of the model for all coupling constant regimes and calculate the impurity free energy. We discuss the high and low energy behavior of the specific heat and conductance for both repulsive and attractive interactions.

John Barton Massachusetts Institute of Technology
Statistical physics, inference, and the host-pathogen dynamics of HIV
One of the principal challenges posed by human immunodeficiency virus (HIV) is its high mutability. HIV evolves rapidly within infected individuals, accumulating mutations that allow the virus to escape from the immune system, thereby preventing control of infection. I will describe how techniques from statistical physics can be applied to HIV sequence data to learn about the selective constraints on HIV proteins. I will show some experimental tests and discuss how this approach allows us to make predictions about how the virus evolves in infected individuals in response to the host immune system. Such predictions may help inform the design of more effective vaccines by cutting off likely avenues of escape for the virus.

Gyan Bhanot Rutgers University
Genetics and Personalized Medicine
Treatment of cancer is becoming personalized. Traditional methods of treatment based on tumor histology/morphology often result in poor outcome. At the Cancer Institute of New Jersey and other major cancer centers, there is a trend towards more personalized treatments based on tumor genetics. Advances in sequencing technologies allow identification of driver tumor mutations even when they are present at low frequencies. Several drugs are now available that target specific mechanisms used by tumors to evade immune surveillance. I will describe some interesting discoveries we have made about tumor biology based on dramatic responses to such treatments in patients with metastatic disease. The talk will be at a general level and accessible to anyone with or without knowledge of biology.
Ravin Bhatt
Princeton University

Disorder driven fractional quantum hall transitions

While there have been several numerical studies of plateau transitions in the integer quantum Hall regime for non-interacting electrons in two dimensions, the study of disorder driven transitions for interacting electrons in the fractional quantum Hall regime has received relatively less attention because of numerical complexity. After reviewing the status of the field, I will describe our recent numerical investigation of the effect of disorder on quantum entanglement properties of the Laughlin state at 1/3 filling (Zhao Liu and R. N. Bhatt, arXiv1607.04762, and in preparation). We find that a suitably defined entanglement entropy function serves as a good diagnostic of the transition from the fractional topological state to an Anderson insulator, and provides a numerically more efficient method of locating the transition than previous methods. Further, it enables a study of the critical behavior, not obtainable previously. Extension to disorder-driven transitions from other fractional states will be briefly described.

*Research supported by United States Department of Energy Office of Basic Energy Sciences

Shobo Bhattacharya
Tata Institute of Fundamental Research

Granular Self-Organization by Auto-tuning of Friction by Rolling and Sliding

A monolayer of granular spheres in a cylindrical vial, driven continuously by an orbital shaker and subjected to a symmetric confining centrifugal potential, self-organizes to form a distinctively asymmetric structure which occupies only the rear half-space. It is marked by a sharp leading edge at the potential minimum and a curved rear. Imaging shows that the regulation of motion of individual spheres occurs via toggling between two types of motion, namely, rolling and sliding. Because the rolling and sliding friction coefficients differ substantially, the spheres acquire a local time-averaged coefficient of friction within a wide range of intermediate values. The various sets of spatial and temporal configurations of the rollers and sliders constitute the internal states of the system. Experiments demonstrate and simulations confirm that the global features of the structure are maintained robustly by autotuning of friction through these internal states, providing a previously unidentified route to self-organization of a many-body system. Recent studies further demonstrate a dynamical phase coexistence between crystals of sliders and a gas of rollers for intermediate drives while pure phases of crystals and gases occur at low and high drives, respectively. Deepak Kumar, Nitin Nitsure, Shankar Ghosh and Shobo Bhattacharya.

Lou Bruch
University of Wisconsin- Madison

Melting of monolayer xenon

David Campbell
Boston University

Graphene Kirigami: Fold, Spindle, and Mutilate

Beginning in 2004 with the isolation of graphene as a single atomic layer—a truly 2D material—by Geim and Novoselov, the study of two-dimensional atomically thin electronic membranes has expanded in many directions, to a host of other materials and to means of physically and chemically modifying these materials to alter their electronic transport, optical, and mechanical properties. In this short presentation, I will discuss some recent work1 on the use of “kirigami”—based on the ancient Japanese art of forming novel structures by making cuts and folds in paper—in graphene to create novel structures that behave as stretchable and tunable quantum dot arrays.


Bulbul Chakraborty
Brandeis University

Stress Transmission in Granular Solids: Beyond the q-Model?

As first illustrated by the Carbon-paper experiments of the Chicago group, force transmission in granular materials occurs via localized structures that have come to be known as force chains. Experiments using photoelastic beads provide clear
Bertrand Duplantier  
Saclay  
**Liouville Quantum Multifractality**

We describe recent advances in the study of the coupling of Schramm--Loewner Evolution (SLE), a canonical model of non-crossing random paths in the plane, to Liouville Quantum Gravity (LQG), a canonical model of random surfaces in 2D quantum gravity. The latter is expected to be the universal, conformally invariant, continuum limit of random planar maps, as weighted by critical statistical models. Various SLE multifractal spectra have natural analogues on random planar maps and in LQG. An example is extreme nesting in the O(n) loop model on a random planar map, as derived recently via combinatorial methods, and extreme nesting in the so-called Conformal Loop Ensemble, as derived by Miller, Watson and Wilson. Their respective large deviations functions are shown to transform one into the other, under a continuous KPZ map inherent to LQG. Other instances are the classical, versus quantum gravity spectra for harmonic measure and windings in SLE. Based in part on joint work with Gaetan Borot and Jérémie Bouttier.

Bob Ecke  
Los Alamos National Laboratory  
**Statistical physics of avalanche behavior in a sheared granular layer coupled to soft elastic plates**

We present stick-slip statistics and real-time dynamics from a granular layer enclosed between two soft compliant boundaries in which one of the boundaries is fixed while the other is translated at very low strain rate. The qualitative spatial distribution of normal and tangential forces acting upon the boundary is indicated by an optical birefringence technique, quantitative local strain measurements are obtained from elastic displacements at the boundary, and global forces are used to investigate short-time dynamics. These probes yield an excellent characterization of the heterogeneous distribution of motion involved in the stick-slip behaviour of the granular layer. In particular, we observe power-law scaling, with an approximate exponent -3/2, of the distribution of small displacement moments whereas large, system-size events are Log-normally distributed [1]. The motions of the granular constituents are also obtained and are strongly correlated with boundary motion. We consider both the fast and slow dynamics of the system from the perspective of an effective friction coefficient and from the point of view that the slip events represent a brittle fracture of the granular layer. We make close comparison with statistical physics models of avalanche behavior and relate our results to naturally occurring earthquake phenomena.

Mark Friesen  
University of Wisconsin- Madison  
**Strongly driven quantum systems: high fidelity gates in a quantum dot hybrid qubit**

Qubit gate operations are typically performed as quickly as possible to minimize the effects of decoherence. For many solid-state devices, this yields Rabi frequencies that are comparable to the qubit frequency. The resulting dynamics are complex and could present a challenge for qubit control. In this talk, I will briefly review the quantum dot hybrid qubit, which was recently proposed by Coppersmith et al., and describe our dressed-state approach for analyzing the dynamics. I will show that potential problems with strong driving, such as leakage outside the qubit subspace, can be suppressed to the point that they are insignificant compared to decoherence.

Pupa Gilbert  
University of Wisconsin- Madison  
**Nacre formation mechanisms**

David Grier  
New York University  
**Light-activated self-thermophoretic swimmers and how they navigate**
We describe colloidal Janus particles with metallic and dielectric faces that swim vigorously when illuminated by defocused optical tweezers, without consuming any chemical fuel. Rather than wandering randomly, these light-activated colloidal swimmers circulate back and forth through the light field, tracing out sinuous rosette patterns. We propose a model for this mode of transport that accounts for the observed behavior through a combination of self-thermophoresis and optically-induced torque. In the deterministic limit, this model yields trajectories that resemble rosette curves known as hypotrochoids. Extensions to swarms of interacting swimmers and more extensive optical-force landscapes will be touched upon briefly.

**Duncan Haldane**
Princeton University

Quantum geometry and flux attachment in a Landau level.

It is widely believed that the holomorphic character of the Laughlin and other model fractional quantum Hall (FQH) states is something to do with “being in the lowest Landau level”. In fact, this “conventional wisdom” is misguided (as should have been realized after Laughlin-like states were observed in the second Landau level) and in fact the holomorphic character is entirely a property of the Heisenberg algebra of non-commuting guiding center degrees of freedom, which obey a non-commutative “quantum geometry”, with no dependence on any particular Landau level. The metric that defines the holomorphic complex structure of the model wavefunctions is an emergent metric defined by the emergent geometry of “flux attachment”. A number of new insights emerge from this reanalysis, including some powerful previously-unrecognized identities that allows a mathematically-exact discretization of periodic compactifications of a Landau level on the torus, and a clearer physical picture of the “flux attachment” that leads to composite-boson FQH states and composite-fermion Fermi liquid stated.

**Joel Lebowitz**
Rutgers University

Human Rights and Responsibility of Scientists

**Jesper Jacobsen**
Ecole Normale

Entanglement in non-unitary quantum critical systems

**Robert Joynt**
University of Wisconsin-Madison

Casimir and the Qubit: Decoherence from Evanescent-wave Johnson Noise

The Casimir effect is an example of the fact that there is a zone of enhanced electromagnetic fluctuations surrounding electrically-active materials - their photon modes leak into the vacuum. This can create problems for qubits situated near metallic objects, as happens in many quantum computer architectures. I show how this effect causes decoherence of charge and spin quantum-dot qubits near metallic gates. Experiments on NV-centers near silver surfaces have confirmed the theory. I present predictions for upcoming experiments on other qubits.

**Randall Kamien**
University of Pennsylvania

Cholesteric Geometry

**Belita Koiller**
Physics Institute, Federal University of Rio de Jainero

Localization and Correlations in Atomically Thin Dopant Chains in Si

Recent experiments report striking properties of donor nanowires in silicon (Si), like metal-insulator transition [1] and ohmic conductance [2]. Given the expected localized character of electronic states in imperfect 1D systems, such results are at least puzzling. We explore such observations and seek for a better understanding of these nanostructures, namely phosphorous (P) arrays in Si, within a model for disordered 1D chains designed to realistically describe donor electrons in Si. We consider the peculiar electronic structure of Si to obtain the Hamiltonian off-diagonal elements, allowing the problem to be treated within a traditional theory of disordered systems. For each chain of donors, electronic states are described as a linear combination of dopant orbitals, with such orbitals obtained from multivalley effective-mass theory. Disorder in donor
positioning is taken into account, leading to an intricate distribution of donor-donor tunnel coupling—an effect of valley interference. A decay length, related to the usual localization length, is obtained for phosphorous (P) donor chains from a transfer-matrix approach and is further compared with the chain length [4].

Electron-electron interaction effects along a 1D finite array were also investigated for ideally positioned donor chains of up to 8 sites. Spin, charge and polarization pair correlation functions indicate an overall antiferromagnetic (AF) ordering at T=0K. The AF behavior is suppressed for T>0K; the decrease is more pronounced as the chain length increases, as expected.

Amintor Dusko, Alain Delgado, Andre Saraiva, Pawel Hawrylak
* work partially supported by the Brazilian agencies CNPq, FAPERJ.


Peter Littlewood
University of Chicago
The physics of jamming and the Mott transition in oxides

Andrea Liu
University of Pennsylvania
Emergent SO(3) symmetry at the frictionless shear-jamming transition.

Andreas Ludwig
University of California- Santa Barbara
Entanglement Spectra of Symmetry Protected Topological (SPT) Phases and Conformal Field Theory

Alan Middleton
Syracuse University
Environment wins over both nature and nurture in a model spin glass
We are interested in exploring what information determines the particular history of the glassy long term dynamics in a disordered material. We study the effect of initial configurations and the realization of stochastic dynamics on the long time evolution of configurations in a two-dimensional Ising spin glass model. The evolution of nearest neighbor correlations is computed using patchwork dynamics, a coarse-grained numerical heuristic for temporal evolution. The dependence of the nearest neighbor spin correlations at long time on both initial spin configurations and noise histories are studied through cross-correlations of long-time configurations and the spin correlations are found to be independent of both. We investigate how effectively rigid bond clusters coarsen. Scaling laws are used to study the convergence of configurations and the distribution of sizes of nearly rigid clusters. The implications of the computational results on simulations and phenomenological models of spin glasses are discussed. In collaboration with Jie Yang

Andrew Millis
Columbia University
Nonequilibrium physics of correlated electrons: dynamically driven phase control
After a brief review of experimental results indicating that a strong enough drive (dc current, terahertz or optical radiation) may be used to induce phases not found in equilibrium, recent theoretical work in this area will be discussed, with particular emphasis on a recent proposal for changing electron-electron interactions via phonon pumping.

Ramis Movassagh
Supercritical violation of the area law for entanglement entropy in quantum spin chains
We will discuss the ground states, frustration free condition and the gap of generic local Hamiltonians \[1,2\]. There is a promising angle of attack to quantify the entanglement of such Hamiltonians that uses a genericity argument from algebraic geometry. This approach naturally motivates the search for specific and highly entangled spin chain models. In recent years, there has been a surge of activities in proposing exactly solvable quantum spin chains with the surprisingly high amount of entanglement entropies (super-logarithmic violations of the area law). We will discuss these models starting from the spin-1 Motzkin spin chain \[3\] to the super-critical colored-Motzkin Hamiltonian, which gives a \(\sqrt{n}\) factor violation of the area law \[4\], to the very recent proposal of Fredkin Spin Chain \[5\]. We will then prove that the gap of \[5\] scales as \(n^{\frac{1}{2}}\), where \(2 \leq c \leq 13/2\) and therefore this model, like \[3,4\], does not have a relativistic conformal field theory description \[6\]. Time permitting we will prove that the gap of a deformation of \[4\] which violates the area law maximally is exponentially small \[7\].

\[1\] Movassagh, Farhi, Goldstone, Nagaj, Osborne, Shor, PRA (2010)
\[3\] Bravyi, Caha, Movassagh, Nagaj and Shor, PRL (2012)
http://www.pnas.org/content/early/2016/11/02/1605716113.abstract

**Giuseppe Mussardo**

SISSA, Trieste

**The Coprime Quantum Chain**

I will discuss the coprime quantum chain, i.e. a strongly correlated quantum system defined in terms of the integer eigenvalues \(n_i\) of the occupation number operators of each site of a chain of length \(M\), with interaction ruled by the coprimality matrix which, for the ferromagnetic case, assigns lower energy to neighbor sites with occupation numbers \(n_i\) and \(n_{i+1}\) that have a common natural divisor, while for the anti-ferromagnetic case, to neighbor sites whose occupation numbers \(n_i\) and \(n_{i+1}\) are coprime numbers. Both in the ferro and anti-ferro magnetic cases, the coprime quantum chain may have an exponential number of ground states and, depending upon extra on-site interactions, it can be driven to different classes of universality, among which the one of the Ising model or the 3-state Potts model.

**Sidney Nagel**

University of Chicago

**Exploiting disorder for global and local response**

In a crystal with only one atom per unit cell, all atoms play the same role in producing the solid's global response to external perturbations. Disordered materials are not similarly constrained and a new principle emerges: independence of bond-level response. This allows one to drive the system to different regimes of behavior by successively removing individual bonds. We can thus exploit disorder to achieve unique, varied, textured and tunable global response. We can use similar pruning techniques to achieve long-range interactions inspired by allosteric behavior in proteins. This allows a local input strain to control the local strain at a distant site in the network.

**Onuttom Narayan**

University of California- Santa Cruz

**Slow dynamics in disordered oscillator chains**

Energy trapping in disordered classical oscillator chains at non-zero temperature is studied. As the localized limit of a harmonic chain is approached, the dynamics are extremely slow, spanning many decades. A scaling collapse of the energy decay curves for various parameters can be obtained. There is no clear evidence for a non-trivial phase with energy localization.
Nick Read  
Yale University  
*Compactly-supported Wannier functions and no-go theorems for free-fermion tensor network states*

Tensor network states are trial states that have proved useful in modeling ground states in many topological phases. Questions arise as to whether they are capable of modeling topological phases with protected gapless edge states. For non-interacting fermions, it is possible to prove that, other than certain topological phases related to one-dimensional cases, non-trivial topological phases cannot be obtained. The results also apply to a type of compactly-supported Wannier functions, of interest in band theory calculations, and are obtained using algebraic K-theory.

Tom Spencer  
IAS  
Classical and quantum dynamics

Uwe Tauber  
Virginia Tech  
*Non-equilibrium Relaxation and Aging Scaling in Driven Systems*

If systems characterized by slow (algebraic) dynamics are prepared in an out-of-equilibrium initial configuration that is quite distinct from its asymptotic equilibrium or non-equilibrium stationary state, one may observe a "physical aging regime" in the ensuing relaxation kinetics that is governed by broken time translation invariance and non-trivial, often universal scaling laws. Dynamical systems near a critical point constitute proto-typical and now well-understood examples. Indeed, measuring critical exponents in the intermediate aging rather than the asymptotic stationary temporal regime has become a standard numerical tool. In this talk, I will demonstrate that these concepts can also be employed to gain a better understanding of both generic scale invariance and critical dynamical scaling in driven system far from thermal equilibrium. I shall first address the critical dynamics [1] and aging scaling [2] for driven-dissipative Bose-Einstein condensation, which in the continuum limit is captured by a noisy complex Ginzburg-Landau or Gross-Pitaevskii equation that also describes the synchronization of coupled non-linear oscillators, as well as various non-equilibrium pattern formation scenarios. Next I will discuss driven lattice gases that relax towards non-equilibrium stationary systems displaying generic scale invariance [3], and the continuous non-equilibrium phase transition in two-dimensional driven Ising lattice gases [4]. Finally, I shall show how critical aging scaling might be employed as a early warning signal for the extinction transition in spatially extended stochastic predator-prey competition models, and to characterize the ensuing directed percolation universality class [5].

This research is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering under Award DE-FG02-09ER46613.

References:

Benjamin Vollmayr-Lee  
Bucknell University  
*Field Theoretic Description of Nonequilibrium Work Relations*

We develop Doi-Peliti field theory for driven interacting classical particles coupled to a thermal bath. The formalism does not require an assumption of large particle numbers or slow modes. As an application, we consider nonequilibrium work relations and show that with the introduction of an auxiliary field, the Jarzynski relation emerges as a direct consequence of time reversal.

Clare Yu  
University of California- Irvine  
*Flux Noise in Superconducting Qubits*
Quantum computers hold out the promise of being massively parallel and thus being able to do calculations much faster than conventional computers. In an ordinary computer a bit is a 0 or a 1. A quantum bit (or a qubit) is a wavefunction that is a linear superposition of a $|0\rangle$ state and a $|1\rangle$ state. The superconducting Josephson junction qubit is one of the leading candidates for making a qubit. A major obstacle to the realization of quantum computers with Josephson junction qubits is noise and decoherence of the wavefunction. One of the major sources of noise is called flux noise and is due to mysterious fluctuating magnetic spins on the surface of metals. We will describe our recent proposal that the microscopic source of this flux noise are oxygen molecules adsorbed on the surface.

Emil Yuzbashyan  
Rutgers University

Non-thermal steady states in long time quench dynamics

The past decade has witnessed an unprecedented experimental access to global coherent dynamics of many-body interacting systems. Interestingly, many of these systems are integrable – they posses a large number of nontrivial conservation laws making the long time dynamics non-thermal. A lot of theory research in this area focused on testing a Generalized version of Gibbs Ensemble (GGE) in various quantum integrable models. However, it makes sense to first look at classical integrable dynamics, especially since there is no accepted unambiguous notion of quantum integrability.

In this talk, I’ll first prove the microcanonical version of GGE – Generalized Microcanonical Ensemble (GME) – for the long time dynamics of classical integrable systems with any number of degrees of freedom. This will also clarify the physical meaning of GGE and GME. Then, I’ll propose a GME for quantum dynamics and argue that it has a number of significant advantages. Namely, this GME is exact in the semiclassical limit for any number of degrees of freedom and, unlike GGE, is suitable for systems with long range interactions. Further, it works whenever GGE does and, moreover, converges faster to the exact answer as the system size increases.