WORKSHOP ON

"DYNAMICS OF STRONGLY CORRELATED QUANTUM SYSTEMS"

ABSTRACTS

Jonathan Keeling

Title: Non-equilibrium coherence in light-matter systems: condensation, lasing and the superradiance transition.

Abstract: Microcavity polaritons - superpositions of confined photons andexcitons in quantum wells - are quasiparticles in semiconductors that may form a condensate. However, they differ from most other quantum condensates in that the quasiparticles have a finite lifetime, and so the steady state involves a flux of particles through the system. They also differ from lasers, in that the quasiparticles are more strongly interacting, and that condensation occurs at much lower densities than those required for inversion and regular lasing.

I will discuss how the Keldysh Green's function approach can be used to study the non-equilibrium steady state of these systems, making use of a microscopic model that is an extension of the Dicke model[1]. This approach will naturally provide a language to connect the extreme limits of simple lasing and equilibrium condensation within a single model and a single framework. This approach also provides an insight into the ingredients necessary to see macroscopic coherence in a system without net inversion, and while remaining in the strong coupling limit. I will also briefly mention recent work[2] on another example of a non-equilibrium light-matter system, of cold atoms in an optical cavity with a perpendicular pump, in which a realisation of the Dicke model phase transition has recently been observed[3].

[1] M. H. Szymańska, J. Keeling and P. B. Littlewood, Phys. Rev. Lett. 96 230602 (2006); Phys. Rev. B, 75 195331 (2007); J. Keeling, M. H. Szymańska, and P. B. Littlewood arXiv:1001.3338.

[2] J. Keeling, M. J. Bhaseen and B. D. Simons arXiv:1002.3108

[3] K. Baumann, C. Guerlin, F. Brennecke and T. Esslinger, Nature 464, 1301 (2010)

Victor Gurarie

Title: Landau-Zener problem in many body systems: applications to cold atoms, cavity QED and superconductivity

Abstract: An old theorem in quantum mechanics states that if the parameters of a system are changed sufficiently slowly, the system remains in its ground state. However, if the system is large, a natural question arises: how slow is slow enough. In this talk, I will introduce two interesting many particle models which do not want to stay in its ground state unless its parameters change at an exceedingly slow rate. One of them is a version of a time-dependent Dicke model. It arises in a variety of contexts in cold atoms, quantum optics, and condensed matter physics. The second model describes cold atoms interacting via Feshbach resonance whose strength depends on time. It also arises in the description of time-dependent superconductors. I will be able to solve both models.

Mark Rudner

Title: Topological Transitions in Dissipative Quantum Transport

Abstract: We investigate dissipative quantum transport in a family of one-dimensional models where a particle can decay whenever it visits sites on one of two sublattices. The corresponding non-Hermitian tight-binding problem exhibits distinct topological phases, characterized by a winding number defined in terms of the Bloch eigenstates in the Brillouin zone. We find that the mean displacement of a particle initially localized on one of the nondecaying sites can be expressed in terms of the winding number, and is therefore quantized as an integer, changing from zero to one at the critical point. Due to the topological nature of this phenomenon, the behavior is robust against some types of noise and decoherence. Finally we discuss the implications of these results for photon pumping in Jaynes-Cummings like systems and for mesoscopic nuclear spin pumping in quantum dots.

A. Imamoglu

Title: Optical manipulation of quantum dot nuclear spins

Abstract: Spins confined in semiconductor quantum dots offer new possibilities for realizing quantum optical systems with unique properties. In this talk, I will describe all-optical measurements that reveal rich spin physics in single self-assembled InAs/GaAs quantum dots. To study electron and nuclear spin dynamics, we used resonant optical excitation of the quantum dot charged-exciton transitions and observed many striking phenomena such as breakdown of nuclear spin temperature approach in demagnetization, anomalous Hanle effect, and nuclear spin polarization that is completely stable against dipolar diffusion. We also observed that optically mediated coupling between electron and nuclear spins could lead to a bi-directional nuclear spin polarization, which in turn allows the electron+nuclear spin system to track the changes in laser frequency dynamically on both sides of the quantum dot resonance. Our measurements reveal that the confluence of the laser excitation and nuclear spin polarization suppresses the fluctuations in the nuclear Overhauser field.

Leonid Levitov

Title: Time-Reversal Symmetry and Temporal Coherent Back-Scattering in a Driven Two-Level System

Corinna Kollath

Title: Quantum dynamics in ultracold atomic gases

Abstract: Recent experimental developments increased the interest in quantum systems far from equilibrium. In particular, the good tunability of ultracold quantum gases now allows for a rapid change of the system parameters and the observation of the subsequent quantum evolution decoupled from the environment. For example the non-adiabatic dynamics across the superfluid-Mott-insulating phase transition has been realized in bosonic gases confined to optical lattices. The theoretical description of these time-dependent phenomena is very involved. We discuss the response of these strongly correlated quantum systems to different parameter changes as a change in their interaction strength.

Marcos Rigol

Title: Quantum chaos and thermalization in finite one-dimensional systems

Abstract: We utilize quantum quenches to study the dynamics and thermalization of hardcore bosons in finite one-dimensional lattices. We show that, far away from integrability, few-body observables thermalize. We then study the breakdown of thermalization as one approaches integrable points. Insights on the different regimes are gained by means of quantum chaos indicators and eigenstate expectation values of few-body observables. We show that thermalization closely follows the onset of quantum chaos and the validity of the eigenstate thermalization hypothesis. Finite size effects and the consequences of crossing a superfluid to insulator transition are discussed in the context of the eigenstate thermalization hypothesis.

Davide Rossini

Title: Thermalization after a quantum quench: the role of many-body localization

Abstract: Recent experiments with ultracold atomic gases have triggered a great deal of interest in some fundamental aspects of the non-equilibrium dynamics of many-body quantum systems. In particular, they raised an intense discussion on the general conditions under which thermalization in the long-time dynamics is observed. We provide evidence that the presence or absence of thermal behavior after a quench does not exclusively depend on the integrability of the model, but also on the considered observable. Even in a perfectly integrable system, operators that are non-local in the quasi-particles of the system can behave thermally, while local operators do not. On the other hand, a non-integrable perturbation causes delocalization in quasi-particle space, thus naturally leading to thermalization: any initial state is allowed to diffuse into all states in a micro-canonical energy shell generating a cascade of all possible lower energy excitations.

Boris Altshuler

Title: Finite superfluid-“insulator” phase transition for disordered bosons in one dimension at finite temperature

It is commonly accepted that there are no phase transitions in one-dimensional systems at a finite temperature, because long-range correlations are destroyed by thermal fluctuations. We demonstrate that the 1D gas of short-range interacting bosons in the presence of disorder can undergo a finite temperature phase transition between two distinct states: fluid and insulator. None of these states has long-range spatial correlations, but this is a true albeit non-conventional phase transition because transport properties are singular at the transition point. In the fluid phase the mass transport is possible, whereas in the insulator phase it is completely blocked even at finite temperatures. We thus reveal how the interaction between disordered bosons influences their Anderson localization. This key question, first raised for electrons in solids, is now crucial for the studies of atomic bosons where recent experiments have demonstrated Anderson localization in expanding very dilute quasi-1D clouds.

The work was done in collaboration with I.L. Aleiner (Columbia University) and G.V. Shlyapnikov (LPTMS, Orsay)

David Weiss

Title: Thermalization of 1D Bose gases

Michele Fabrizio

Title: Quantum quenches in correlated systems: proposal for a variational approach

Abstract: We introduce a variational ansatz for the dynamical behavior of a correlated system after a quantum quench that preserves energy conservation and reproduces the correct dynamics of a selected number of local operators. In the simplest case of a half-filled Hubbard model subject to a sudden change of interaction, we show that the dynamical evolution corresponds to that of a Ising model in a transverse field, which, at the mean field level, displays a dynamical transition like that of a classical pendulum.

L.I. Glazman

Title: Nonlinear Luttinger Liquids

Abstract: We developed a generalization of the Luttinger liquid theory to include a generic nonlinear dispersion relation of 1D quantum particles (bosons or fermions) comprising the fluid. The generalization allowed us to find the threshold singularities in the momentum-resolved dynamic response functions at arbitrary momenta. One of the most important dynamic correlation functions we consider is the electron spectral function for momenta arbitrarily far away from the Fermi points. This spectral function is directly measurable in tunneling experiments. That type of experiments recently confirmed also a prediction regarding the kinetics of a nonlinear Luttinger liquid, the violation of particle-hole symmetry of the electron energy relaxation time.

Yuval Gefen

Title: Luttinger Liquids Out of Equilibrium

A. J. Millis

Title: Quantum Monte Carlo on the Keldysh Contour

Abstract: An overview will be given of recent work on application of diagrammatic quantum Monte Carlo methods to nonequilibrium impurity models. The basic ideas will be outlined, strengths and weaknesses of different approaches will be compared and results on nonequilibrium transport through quantum dots will be presented. Prospects for future work will be mentioned. This work has been performed in collaboration with P. Werner and E. Gull and supported by the US NSF under grant DMR-0705847.

Natan Andrei

Title: Quenching in Impurity models

Yariv Kafri

Title: Fluctuations and Large Deviations far from Equilibrium

V. Gritsev

Title: Nonequilibrium dynamics of integrable and nearly integrable many-body systems.

Abstract:
Quantum nonequilibrium dynamics of many-body integrable or nearly integrable systems has recently attracted a lot of attention because of experimental advance in cold atomic systems. Both limits of slow and fast quenches have their universal features, which can be studied theoretically and observed experimentally. First I will give an overview of various methods for studying quenches and slow dynamics in quantum many-body interacting integrable systems. I will illustarte these methods on various models from cold atoms and quantum optics where parameters can be controlled in real time.

Blair Blakie

Title: Dynamics and statistical mechanics of ultra-cold Bose gases using c-field techniques

Abstract: I will discuss phase space techniques based on the Wigner representation that provide an approximate description of dilute ultra-cold Bose gases. In this approach the quantum field evolution can be represented using equations of motion of a similar form to the Gross-Pitaevskii equation but with stochastic modifications that include quantum effects in a controlled degree of approximation. These techniques provide a practical quantitative description of both equilibrium and dynamical properties of Bose gas systems. We develop versions of the formalism appropriate to zero temperature, where quantum fluctuations can be important, and at finite temperature where thermal fluctuations dominate. Applications to a range of phenomena will be discussed.

Gil Refael

Title: Putting Floquet Hamiltonians to work: Dyson singularity and topological phases in time-periodic hamiltonians

Abstract: My talk will explore how to engineer special classes of hamiltonians using a time varying perturbations. I will first show how to use time-dependent random perturbations in an optical lattice system to realize particle-hole symmatric disorder. Such systems exhibit a universal Dyson singularity of the density of states, but were never realized experimentally because of its instability towards Anderson localization. The second example will make contact with the recent discoveries of topological insulators, and will demonstrate how to induce a topological phase in a non-topological band structure using a periodic time-dependent perturbation.

Eugene Demler

Title: Spin dynamics of ultracold atoms

Abstract: I will discuss nonequilibrium dynamics of spin systems in 1d traps and in optical lattices.

Immanuel Bloch

Title: Non-equilibrium Dynamics of Strongly Interacting Bosonic and Fermionic Quantum Gases

Abstract:
Ultracold quantum gases offer novel and intriguing possibilities to probe the dynamical evolution of strongly correlated quantum systems far from equilibrium. We report on recent experiments, in which we have analyzed the transport behaviour of fermionic quantum gases in an optical lattices. We find three distinct transport regimes for non-interacting, weakly- and strongly-interacting quantum gas mixtures for both attractive and repulsive interactions. In a second series of experiments we probe the quantum dynamics of 1D ladder systems far from equilibrium. Here we investigate generalized Landau-Zener

transitions between two Luttinger liquids, for which we find striking effects of ground state phase transitions that manifest in the dynamical evolution of the system. Finally, we show how quantum collapses and revivals of a bosonic matter wave field can be used to reveal the number statistics of the particles on the lattice and to detect multi-particle interactions up to the case of six-particle interactions.

Mukund Vengalattore

TBA

Krishnendu Sengupta

Title: Slow dynamics in quantum critical systems

Abstract: In recent times, there has been a lot of interest in defect production in quantum critical systems due to their slow non-equilibrium dynamics through quantum critical point. It is well-known that the density of defects produced n, during a slow linear time evolution which takes the system through one gapped phase to the another through an intermediate critical point, has an universal scaling with the quench time τ: $ n \sim \tau^{-\nu d /(z\nu +1)$.. In this talk, I am going to discuss extension of such scaling to a) dynamics across a quantum critical surface , b) non-linear power-law dynamics and c) dynamics around anisotropic critical points.

Hans Peter Buechler

Titel: Quantum critical behavior in driven and strongly interacting Rydberg gases

Abstract: We study the appearance of correlated many-body phenomena in an ensemble of atoms driven resonantly into a strongly interacting Rydberg state. The ground state of the Hamiltonian describing the driven system exhibits a second order quantum phase transition. We derive the critical theory for the quantum phase transition and show that it describes the properties of the driven Rydberg system in the saturated regime. We find that the suppression of Rydberg excitations known as blockade phenomena exhibits an algebraic scaling law with a universal exponent.

Gerardo Ortiz

Title: Dynamical critical scaling in finite-order quantum phase transitions

We study the emergence of dynamical scaling in quantum critical spin systems adiabatically driven out of equilibrium, with emphasis on quench dynamics which involves non-isolated critical points, i.e. critical regions, and multicritical points. Comparing to the case of an isolated quantum critical point, we find that non-equilibrium scaling behavior of a large class of physical observables may still be explained in terms of critical exponents which depend not only on the control path but also on detailed knowledge of the time-dependent excitation process. Depending on the universality class anomalous critical exponents (non-Kibble-Zurek-like scaling) may emerge. A large class of initial excited states may still show dynamical scaling, with critical exponents that are combinations of the ground state static critical exponents.

Martin Plenio

TBA