TT 64: Correlated Electrons: Nonequilibrium Quantum Many-Body Systems 1

Time: Thursday 9:30–13:00 Location: H22

TT 64.1 Thu 9:30 H22

Efficient numerical simulations of many-body localized systems — •Frank Pollmann[1], Vedika Khemani[2], and Shivaji Sondhi1[2] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Physics Department, Princeton University, Princeton, NJ 08544, USA

Many-body localization (MBL) occurs in isolated quantum systems when Anderson localization persists in the presence of finite interactions. To understand this phenomenon, the development of new, efficient numerical methods to find highly excited eigenstates is essential. We introduce a variant of the density-matrix renormalization group (DMRG) method that obtains individual highly excited eigenstates of MBL systems to machine precision accuracy at moderate-large disorder. This method explicitly takes advantage of the local spatial structure characterizing MBL eigenstates.

TT 64.2 Thu 9:45 H22

Many-Body Localization in the central spin model — •Daniel Hetterich[1], Maksym Serbyn[2], Norman Yao[2], Frank Pollmann[3], and Björn Trauzettel[1] — [1]Institut für theoretische Physik, Universität Würzburg, Würzburg, Germany — [2]Department of Physics, University of California, Berkeley, USA — [3]Max-Plank-Insitut für Physik komplexer Systeme, Dresden, Germany

The periodic Heisenberg chain model obeys signatures of many-body localization (MBL) that persist the insertion of a central spin, which interacts with all other spins of the periodic chain. To support this statement, we present numerical results for the level repulsion of eigenvalues and for the growth of entanglement entropy of subsystems. We discuss why the central spin is not destroying the transition from the thermal phase to the localized phase. Surprisingly, local observables that measure the central spin only can be used to detect MBL within the whole system. Finally, more realistic modifications of our model are addressed by which we depict the experimental relevance of our results for quantum dots.

TT 64.3 Thu 10:00 H22

Many-body localization dynamics from a one-particle perspective — •Talía Lezama Mergold Love, Soumya Bera, and Jens Hjorleifur Bardarson — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany.

Systems exhibiting many-body localization (Anderson insulators in the presence of interactions) present a novel class of nonergodic phases of matter. The study of entanglement, in terms of both exact eigenstates and its time evolution after quenches, has been useful to reveal the salient signatures of these systems. Similarly to the entanglement entropy of exact eigenstates, the one-particle density matrix can be used as a tool to characterize the many-body localization transition with its eigenvalues showing a Fermi-liquid like step discontinuity in the localized phase. However, this analysis distinguishes the Fock-space structure of the eigenstates from the real space. Here, we present numerical evidence for dynamical signatures of the many-body localized phase for a closed fermionic system, using the one-particle density matrix and its time evolution after a global quench. We discuss and compare our results with the well-known logarithmic spreading of entanglement (a dynamical signature of this phase, absent in the Anderson insulator).

TT 64.4 Thu 10:15 H22

Stroboscopic prethermalization in weakly interacting periodically driven systems — Elena Canovi[1], •Marcus Kollar[2], and Martin Eckstein[1] — [1]Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL — [2]Theoretical Physics III, Center for Electronic Correlations and Magnetism, University of Augsburg

Time-periodic driving provides a promising route to engineer non-trivial states in quantum many-body systems. However, while it has been shown that the dynamics of integrable systems can synchronize with the driving into a non-trivial periodic motion, generic non-integrable systems are expected to heat up until they display a trivial infinite-temperature behavior. Here we show that a quasi-periodic time evolution over many periods can also emerge in systems with weak integrability breaking, with a clear separation of the timescales for synchronization and the eventual approach of the infinite-temperature state [1]. This behavior is the analogue of prethermalization in quenched systems. The synchronized state can be described using a macroscopic number of approximate constants of motion. We corroborate these findings with numerical simulations for the driven Hubbard model.

[1] E. Canovi, M. Kollar, M. Eckstein, arXiv:1507.00991

TT 64.5 Thu 10:30 H22

An impurity solver for nonequilibrium dynamical mean field theory based on hierarchical quantum master equations — •Rainer Härtle[1] and Andrew J. Millis[2] — [1]Institut für theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany — [2]Department of Physics, Columbia University, New York, USA

We present a new impurity solver for real-time and nonequilibrium dynamical mean field theory applications, based on the recently developed hierarchical quantum master equation approach [1,2]. Our method employs a hybridization expansion of the time evolution operator, including an advanced, systematic truncation scheme [2]. Convergence to exact results for not too low temperatures has been demonstrated by a direct comparison to quantum Monte Carlo simulations [3]. The approach is time-local, which gives us access to slow dynamics such as, e.g., in the presence of magnetic fields or exchange interactions and to nonequilibrium steady states [3,4]. Here, we present first results of this new scheme for the description of strongly correlated materials in the framework of dynamical mean field theory, including benchmark and new results for the Hubbard and periodic Anderson model.

[1] J. Jin *et al.*, J. Chem. Phys. **128**, 234703 (2008)
[2] R. Härtle *et al.*, PRB **88**, 235426 (2013)
[3] R. Härtle *et al.*, PRB **92**, 085430 (2015)
[4] R. Härtle *et al.*, PRB **90**, 245426 (2014)

TT 64.6 Thu 10:45 H22

Irreversibility in Quantum Many-Body Systems — •Markus Schmitt and Stefan Kehrein — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

The question of thermalization in closed quantum many-body systems has received a lot of attention in the past few years. An intimately related question is whether a closed quantum system shows irreversible dynamics. However, irreversibility and what we actually mean by this in a quantum many-body system with unitary dynamics has been explored very little. In our work we investigate the irreversibility of dynamics in quantum many-body systems by studying echo dynamics. In order to quantify the (ir)reversibility we study the time evolution involving an imperfect effective time reversal. Our measure for the recovery of the initial state are the echo peaks occurring in the time evolution of observables. Specifically, we investigate non-interacting and interacting one-dimensional spin chains. We study the characteristics of the echo peak decay and especially focus on whether this depends on the (non-)integrability of the model.

TT 64.7 Thu 11:00 H22

Unruh effect in nonequilibrium quench dynamics — •Manuel Kreye and Stefan Kehrein — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

Recent experimental advances have opened up the field of nonequilibrium quench dynamics. Of particular importance is the question under what conditions quenched systems reach thermalization. For many-body systems with a quadratic Hamiltonian the time evolution is governed by a Bogoliubov transformation. Interestingly, such a transformation is also found in quantum field theory when coordinates are changed from Minkowski to Rindler space, where the latter is used by an accelerated observer. This transformation leads to the Unruh effect, i.e. the fact that the accelerated observer sees particles at a temperature proportional to acceleration.

We discuss the construction of a quadratic many-body Hamiltonian where the time evolution is governed by exactly the same Bogoliubov transformation that generates the Unruh effect. Our analysis shows that one can achieve thermalization only for half the modes by using a specific many-body Hamiltonian that describes parametric pair production. The time evolution turns out to be quite similar to the one from the Unruh effect.

15 min. break

TT 64.8 Thu 11:30 H22

Statistical analysis of the flow equation method for intermediate flow parameters — •Nils O. Abeling and Stefan Kehrein — Institut für Theoretische Physik, Göttingen, Germany

The flow equation approach is an RG-like method employing continuous unitary transformations to map an initial Hamiltonian to an effective Hamiltonian which takes on a simple banded form [1]. In our work we study the properties of the effective Hamiltonian for intermediate flow parameters when only off-diagonal matrix elements with large energy differences (as compared to the many-body level spacing) have been eliminated. In this case, we show that the diagonal elements already contain the necessary information for a time evolution until a certain maximum time. The remaining off-diagonal matrix elements can be interpreted as a banded random matrix.

[1] F. Wegner, Ann. Phys. **506**, 77 (1994)

TT 64.9 Thu 11:45 H22

Slow relaxing electronic dynamics at the Mott transition — •Sharareh Sayyad and Martin Eckstein — Max Planck Institute for the Structure and Dynamics of Matter, University of Hamburg-CFEL, 22761 Hamburg, Germany

While electron thermalization in metals is usually very fast, we propose a slow-down of the electronic relaxation around the metal-insulator crossover regime. Using nonequilibrium slave-rotor dynamical mean field theory, we studied the one-band Hubbard model, weakly coupled to a dissipative bosonic bath. After a slow quench of the hopping amplitude, the relaxation starts from the bad metal and is headed to the good metal forming the quasiparticle. The timescale of the dynamics is dominated by the spinon equilibrium physics. The spinon evolution goes through a U-turn, governed by a nonmonotonous temperature dependence of the bandwidth in equilibrium. In companion to this evolution, the rotor is forming low-energy spectral weight. Although, before the turning point, the rotor is able to build up the spectral density, it takes time to go along with the spinon after the turn.

TT 64.10 Thu 12:00 H22

Lehmann representation of the nonequilibrium self-energy — •Christian Gramsch[1,2] and Michael Potthoff[1,2] — [1]I. Institute for Theoretical Physics, University of Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

It is shown that the nonequilibrium self-energy of an interacting lattice-fermion model has a unique Lehmann representation. Based on the construction of a suitable non-interacting effective medium, we provide an explicit and numerically practicable scheme to construct the Lehmann representation for the self-energy, given the Lehmann representation of the single-particle nonequilibrium Green's function. This is of particular importance for an efficient numerical solution of Dyson's equation in the context of approximations where the self-energy is obtained from a reference system with a small Hilbert space. As compared to conventional techniques to solve Dyson's equation on the Keldysh contour, the effective-medium approach allows to reach a maximum propagation time which can be several orders of magnitude longer. This is demonstrated explicitly by choosing the nonequilibrium cluster-perturbation theory as a simple approach to study the long-time dynamics of an inhomogeneous initial state after a quantum quench in the Hubbard model on a 10x10 square lattice. We demonstrate that the violation of conservation laws is moderate for weak Hubbard interaction and that the cluster approach is able to describe prethermalization physics.

TT 64.11 Thu 12:15 H22

Real-time dynamics after a parameter quench in the two-dimensional Kondo-lattice model with classical spins — •Lena-Marie Gebauer, Mohammad Sayad, and Michael Potthoff — I. Institut für Theoretische Physik, Universität Hamburg

The two-dimensional ferromagnetic Kondo lattice with localized spins coupled to a system of non-interacting conduction electrons is the prototypical model for layered manganites and can be simulated using ultracold fermions trapped in optical lattices. Here, we present a quantum-classical hybrid theory for the thermodynamics and the real-time dynamics of the model where the spins are treated as classical degrees of freedom. The relaxation of a single localized spin, the associated energy and spin dissipation and retardation effects are studied for a one-dimensional Kondo-impurity system [1]. For the lattice variant of the model in two dimensions, the equilibrium phase diagram is derived and found to agree well with previous classical Monte-Carlo data [2]. It comprises different phases, an antiferromagnet at half-filling as well as ferromagnetic, incommensurate and phase-separated states. We study the exact real-time dynamics initiated by quenches of the exchange coupling constant across different phase boundaries.

[1] M. Sayad, M. Potthoff, NJP (in press), arXiv:1507.08227
[2] S. Yunoki et al., PRL **80**, 845 (1998)

TT 64.12 Thu 12:30 H22

How to guarantee complete positivity in approximations to open-system dynamics: Kraus theorem on the Keldysh contour — •Viktor Reimer[1,2] and Maarten Rolf Wegewijs[1,2,3] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA-Fundamentals of Future Information Technology — [3]Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany

A fundamental problem in the theory of open quantum systems is how to guarantee that the time-evolution within a nontrivial approximation scheme results in a valid physical mixed state.

Spurred by a crucial work of van Wonderen and Suttorp [1], we present a general framework based on the Kraus representation of the exact reduced system dynamics, in which positivity-, hermicity- and trace-preserving approximations can be systematically formulated. We relate the Kraus operators to the standard real-time Keldysh diagrammatic expansion and identify precisely which partial resummations of such diagrams strictly enforce complete positivity of the density operator. This allows the derivation of time-nonlocal quantum master equations with approximate kernels that strictly preserve complete positivity.

[1] A. J. van Wonderen and L. G. Suttorp, EPL **102**, 60001 (2013)

TT 64.13 Thu 12:45 H22

Nonequilibrium dynamics on Chern bands — Sthitadhi Roy, •Adolfo Grushin, Roderich Moessner, and Masudul Haque — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The experimental realization of lattices with Chern bands in ultracold-atom and photonic systems has motivated the study of time-dependent phenomena, such as spatial propagation on such systems. We show that the transverse response to the force due to a harmonic trap on a wavepacket on a Chern lattice, arising due to the interplay of Berry curvature and band dispersion can be captured accurately if the extent of the wavepacket in momentum space is taken into account, unlike point-particle semiclassics. Moreover, if the wavepacket is prepared with a finite initial momentum, the semiclassical analysis reproduces its motion as long as it has a large overlap with the eigenstates of a single band. Relevant for fermionic systems, we study the dynamical evolution of Chern insulator after subjecting them to local quenches. For open-boundary systems, we show for half-filling that the chiral nature of edge states is manifested in the time-dependent chiral response to local density quenches on the edge. In the presence of power-law traps, we show how to mimic the half-filling situation by choosing the appropriate number of fermions depending on the trap size, and explore chiral responses of edges to local quenches in such a configuration. Our results provide different routes to check dynamically the non-trivial nature of Chern bands.