TT 19: Correlated Electrons: Nonequilibrium Quantum Many-Body Systems 2 (jointly with DY)

Time: Monday 15:00–18:00 Location: H 3010

TT 19.1 Mon 15:00 H 3010

Quenching the Anisotropic Heisenberg Chain: Exact Solution and Generalized Gibbs Ensemble Predictions — •Bram Wouters[1], Jacopo De Nardis[1], Michael Brockmann[1], Davide Fioretto[1,2], Marcos Rigol[3], Rogier Vlijm[1], and Jean-Sébastien Caux[1] — [1]Institute for Theoretical Physics, University of Amsterdam, Science Park 904, Postbus 94485, 1090 GL Amsterdam, Netherlands — [2]Institute for Theoretical Physics, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [3]Department of Physics, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

We study quantum quenches in integrable spin $\frac{1}{2}$ chains in which we evolve the ground state of the antiferromagnetic Ising model (i.e. the zero momentum Néel state) with the anisotropic Heisenberg Hamiltonian (with anisotropy $\Delta \geq 1$). For this nontrivially interacting situation, an application of the first-principles-based quench-action method allows us to give an exact description of the postquench steady state in the thermodynamic limit.We show that a generalized Gibbs ensemble, implemented using all known local conserved charges, fails to reproduce the exact quench-action steady state and to correctly predict postquench equilibrium expectation values of physical observables. This is supported by numerical linked-cluster calculations within the diagonal ensemble in the thermodynamic limit.

TT 19.2 Mon 15:15 H 3010

Auxiliary master equation approach to nonequilibrium correlated impurities: a matrix product states treatment — •Antonius Dorda, Wolfgang von der Linden, and Enrico Arrigoni — Graz University of Technology, Graz, Austria

The auxiliary master equation approach [1,2] allows for a direct and efficient calculation of steady state properties of correlated impurity problems out of equilibrium, as is needed e.g. for nonequilibrium dynamical mean field theory [3]. The basic idea is to replace the original impurity problem by an auxiliary one, described by an open quantum system consisting of a finite number of bath sites embedded in a Markovian environment. The system dynamics are then described by a Lindblad equation, in which the different bath parameters are optimized by fitting the bath hybridization function in Keldysh space. Upon increasing the number of bath sites, the results can be systematically improved and the solution of the auxiliary system converges towards the exact one. A systematic study using a non-Hermitian Lanczos solver has been carried out [1] and a good agreement with reference values was found already for rather small system sizes. In order to further increase the accuracy, matrix product states are employed to address the interacting Lindblad problem, which enables one to consider larger system sizes.

[1] A. Dorda et al., Phys. Rev. B 89, 165105 (2014)
[2] E. Arrigoni et al., Phys. Rev. Lett. 110, 086403 (2013)
[3] J. K. Freericks et al., Phys. Rev. Lett. 97, 266408 (2006)

TT 19.3 Mon 15:30 H 3010

Wannier-Stark Resonances in the current characteristics of an one-dimensional tight-binding chain and graphene nanoribbons: The role of interactions and dissipation — •Jakob Neumayer, Enirco Arrigoni, and Wolfgang von der Linden — Institut für Theoretische Physik - Computational Physics, Technische Universität Graz, Österreich

Electronic transport investigations of an infinite one-dimensional tight-binding chain and infinitely long graphene nanoribbons are performed within the Wannier-Stark model, where a homogeneous electric field is applied along the overall structure to drive a current to flow. Dissipation is represented in a simplified way by coupled voltage probes (artificial fermion bath chains) instead of an explicit consideration of phonons, to prevent an occurrence of Bloch Oscillations within the infinite geometries. Cluster Perturbation Theory is used to allow for an effective inclusion of electron correlations into the considered model.

Appearing Wannier-Stark resonances in the steady-state current characteristics of the correlated one-dimensional chain and graphene nanoribbons demand for a comprehensive understanding of the physical transport processes within the Wannier-Stark model, which is gained by an investigation of the physical system in terms of occurring resonant tunnelling processes. A non-interacting one-dimensional model system with alternating on-site energies is presented in conclusion, reproducing the current characteristics of the correlated tight-binding chain and allowing for a thorough explanation of the found oscillatory current behaviour.

TT 19.4 Mon 15:45 H 3010

Dynamics after connecting two fermionic chains — •Jacopo Viti[1], Jean-Marie Stephan[1], Jerome Dubail[2], and Masud Haque[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Straße 38, 01187 Dresden — [2]Universite de Lorraine, 34 Cours Léopold, 54000 Nancy, France

I will consider a simple out-of-equilibrium protocol: Two one-dimensional systems of free fermions are initially prepared at different densities and/or temperatures; they are then joined together and allowed to evolve unitarily. I will describe the time evolution of two-point correlation functions, discussing in particular their stationary value and the way the steady regime is attained. Particle and thermal currents will be also analyzed. A description in terms of the semi-classical Wigner function will be presented.

TT 19.5 Mon 16:00 H 3010

Real-time dynamics of energy currents in perturbed Heisenberg spin-1/2 chains — •Robin Steinigeweg[1], Jacek Herbrych[2], Jochen Gemmer[3], and Wolfram Brenig[1] — [1]Institute for Theoretical Physics, Technical University Braunschweig, Germany — [2]CCQCN, University of Crete, Greece — [3]Department of Physics, University Osnabrück, Germany

We use the concept of typicality to study the real-time dynamics of energy currents in nonintegrable spin-1/2 models in one dimension and at nonzero temperatures. These models are perturbed XXZ chains, where the integrability-breaking perturbation is either a staggered magnetic field or a complex exchange-coupling structure. Within linear response theory, we numerically calculate autocorrelation functions by propagating a single pure state, drawn at random as a typical representative of the full statistical ensemble. By comparing to small-system data from exact diagonalization and existing data from tDMRG, we show that typicality is satisfied in finite systems over a wide temperature range and valid in both, integrable and nonintegrable systems. We also confirm the validity of our approach by comparing to spectra from Lanczos diagonalization. For the large system sizes treatable, we observe little finite-size effects for large and small perturbation strengths. This allows us to obtain the full relaxation curve of the energy current and to determine the scaling of the heat conductivity.

[1] R. Steinigeweg, J. Gemmer, W. Brenig, PRL 112, 120601 (2014).
[2] R. Steinigeweg, J. Gemmer, W. Brenig, arXiv:1408.6837 (2014).
[3] R. Steinigeweg, J. Herbrych, W. Brenig, in preparation.

TT 19.6 Mon 16:15 H 3010

Dynamical Quantum Phase Transitions in the Kitaev Honeycomb Model — •Markus Schmitt and Stefan Kehrein — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

The notion of a dynamical quantum phase transition (DQPT) was recently introduced by Heyl et al. as the non-analytic behaviour of the dynamical free energy at critical times in the real time evolution of quantum systems in the thermodynamic limit [Heyl et al., Phys. Rev. Lett., 110:135704, 2013]. We present results for the quench dynamics in the vortex-free sector of the two-dimensional Kitaev honeycomb model, which can be mapped to BCS-form, regarding the occurrence of DQPTs. For general two-dimensional systems of BCS-type the zeros of the dynamical partition function coalesce to areas in the thermodynamic limit and DQPTs are of second order. In the Kitaev honeycomb model these DQPTs occur after quenches across a phase boundary or within the massless phase. Considering the 1d limit of the Kitaev honeycomb model it becomes clear that the higher order of the DQPTs is intimately related to the higher dimensionality of the non-degenerate model. Moreover, a conjectured connection between the appearance of DQPTs and ergodicity, which becomes manifest as a relation between the long time limit of the dynamical free energy and the fidelity, is found to hold for the Kitaev honeycomb model.

15 min. break.

TT 19.7 Mon 16:45 H 3010

Real-time dynamics of lattice bosons from nonequilibrium dynamical mean-field theory — •Hugo Strand[1], Martin Eckstein[2], and Philipp Werner[1] — [1]Department of Physics, University of Fribourg, Fribourg, Switzerland — [2]Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, Hamburg, Germany

We extend bosonic dynamical mean-field theory to nonequilibrium situations in combination with a Nambu strong coupling impurity solver [1]. As a first application we study bosonic cold-atoms in an optical lattice using the Bose-Hubbard model and investigate the Mott insulating, superfluid and normal phases at finite temperatures. We perturb the system by quenching the interaction, mimicking the seminal experiment of Greiner et al. [2], and study its time-evolution. Starting from both the normal and superfluid phase, we map out nonequilibrium phase diagrams of the different dynamical regimes, such as rapid thermalization, and trapping in meta-stable normal and superfluid states. Depending on parameters, the condensate displays long lived or strongly damped amplitude oscillations. Nonequilibrium bosonic dynamical mean-field theory can directly be extended to nonequilibrium bosonic multi-component systems [3] and Bose-Fermi mixtures [4].

[1] HS, ME, PW arXiv:1405.6941.
[2] M. Greiner, O. Mandel, T. W. Hansch, I. Bloch,
Nature 419, 51 (2002).
[3] A. Hubener, M. Snoek, W. Hofstetter, PRB 80, 245109 (2009).
[4] P. Anders, P. Werner, M. Troyer, M. Sigrist, L. Pollet,
PRL 109, 206401 (2012).

TT 19.8 Mon 17:00 H 3010

Dynamical phase transitions in the mean field Ising model — •Ingo Homrighausen and Stefan Kehrein — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

The complexity of quantum many body physics leads to interesting phenomena far from equilibrium. An accessible quantity that characterizes the non-equilibrium quantum dynamics after a quantum quench is the return probability (Loschmidt echo). Dynamical phase transitions (DPTs) are defined as non-analyticities in the time-dependence of the return probability rate function in the thermodynamic limit. These DPTs were first observed in the one dimensional transverse-field Ising model for quenches across the quantum critical point [1]. Thereafter they have been studied mostly in low-dimensional exactly solvable models. We investigate the existence of DPTs in the infinite-dimensional mean field limit of the transverse-field Ising model. Now, in contrast to the one-dimensional case, DPTs occur for quenches across the equilibrium phase boundary as well as for quenches within the ordered phase. Moreover, in addition to the non-analytic behavior of the return probability we also find non-analyticities in the rate function of the work distribution for non-zero work. Based on a semi-classical analysis we explain the mechanism behind our findings.

[1] Heyl et al., Phys. Rev. Lett. 110, 135704 (2013)

TT 19.9 Mon 17:15 H 3010

Many-body localization and quantum ergodicity in disordered long-range Ising models — Philipp Hauke[1] and •Markus Heyl[2] — [1]Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, 6020 Innsbruck, Austria

Ergodicity in quantum many-body systems is - despite its fundamental importance - still an open problem. Many-body localization provides a general framework for quantum ergodicity, and may therefore offer important insights. In this talk, it will be shown using both numerical and analytical methods that long-range interacting Ising models with transverse-field disorder enter a many-body localized phase at infinite temperature, irrespective of the disorder strength. As a consequence, these systems are nonergodic. To characterize and quantify quantum ergodicity, a measure for distances in Hilbert space will be introduced. It will be shown that in spin-1/2 systems it is equivalent to a simple local observable in real space, which can be measured in current experiments of superconducting qubits, polar molecules, Rydberg atoms, and trapped ions.

TT 19.10 Mon 17:30 H 3010

Statistical properties of all eigenstates in isolated quantum systems — •Wouter Beugeling, Alexei Andreanov, Roderich Moessner, and Masud Haque — Max-Planck-Institut für Physik komplexer Systeme (MPIPKS), Dresden, Germany

Traditionally, the focus of research in quantum many-body systems has been the ground state and low-lying excited states. For isolated quantum systems, however, the complete spectrum is relevant, because a mechanism that lets the system equilibrate to low energy is absent. The eigenstates in the bulk of the spectrum have significantly different properties than those at the edge, which shows for instance in the entanglement entropy, which typically follows a volume law in the bulk and an area law at the edge.

In this talk, I will discuss the typical behaviour of entanglement entropy and participation ratios of eigenstates as a function of location in the spectrum. Motivated by the similar behaviour of high values in the bulk and low values at the edge, and by the interpretation of both as measures of randomness in the eigenstates, we quantitatively analyse the correlation between the two quantities. We connect their behaviour to that of diagonal and off-diagonal matrix elements of local observables. To this end, we study the dependence on system size and on the amount of integrability breaking, which we introduce by looking at tunable Hamiltonians.

TT 19.11 Mon 17:45 H 3010

Real-time polaron formation: a nonequilibrium DMFT study — •Sharareh Sayyad and Martin Eckstein — Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, Hamburg, Germany

To characterize the real-time polaron formation, we study the interaction-quench in the one-band Holstein model for the low density limit of carriers [1]. In this talk, first, we will briefly discuss the exact nonequilibrium self-energy within the framework of the dynamical mean field theory. Furthermore, we will describe the emergence of a polaron in the strong coupling limit, which is indicated by the splitting the band into the “dressed” electronic band as well as a dispersion-less “polaronic” one. Finally, we will investigate the properties of the real-time formed-polaron and compare them to their equilibrium counterparts.

[1] Sh. Sayyad, M. Eckstein, arXiv:1410.4298(2014).