DY 19: Nonequilibrium Quantum Many-Body Systems 1 (joint session TT/DY)

Time: Tuesday 9:30–13:00 Location: HSZ 204

DY 19.1 Tue 9:30 HSZ 204

Exponential damping in perturbed quantum many-body systems — •Jonas Richter[1], Fengping Jin[2], Lars Knipschild[1], Hans De Raedt[3], Kristel Michielsen[2], Jochen Gemmer[1], and Robin Steinigeweg[1] — [1]University of Osnabrück, Germany — [2]Forschungszentrum Jülich, Germany — [3]University of Groningen, The Netherlands

Given a quantum many-body system and the expectation-value dynamics of some operator, we study how this reference dynamics is altered due to a perturbation of the system's Hamiltonian. Based on projection operator techniques, we unveil that if the perturbation exhibits a random-matrix structure in the eigenbasis of the unperturbed Hamiltonian, then this perturbation effectively leads to an exponential damping of the original dynamics. Employing a combination of dynamical quantum typicality and numerical linked cluster expansions, we demonstrate that our theoretical findings are relevant for the dynamics of realistic quantum many-body models. Specifically, we study the decay of current autocorrelation functions in spin-1/2 ladder systems, where the rungs of the ladder are treated as a perturbation to the otherwise uncoupled legs. We find a convincing agreement between the exact dynamics and the lowest-order prediction over a wide range of interchain couplings, even if the perturbation is not weak.

[1] J. Richter et al., arXiv:1906.09268.

DY 19.2 Tue 9:45 HSZ 204

Slow quantum thermalization and many body revivals from mixed phase space — •Alex Michailidis[1], Chris Turner[2], Dimitry Abanin[3], Zlatko Papic[2], and Maksym Serbyn[1] — [1]IST Austria, Klosterneuburg, Austria — [2]University of Leeds, Leeds, United Kingdom — [3]University of Geneva, Geneva, Switzerland

Isolated, interacting quantum systems thermalize when local measurements are distributed according to the Gibbs ensemble. The ability of an isolated quantum many body system to thermalize is tied to the absence of an extensive set of integrals of motion. The thermalization rate may, however, depend strongly on the initial state. A class of kinetically constraint systems [Nat. Phys. 14, 745 (2018)] displays such features, due to a set of quasi-eigenmodes, known as "quantum many body scars", which form a slowly thermalizing subspace. The slow thermalization is also associated to an unstable periodic orbit in a slightly entangled manifold of matrix product states (MPS) [PRL 122, 040603 (2019)] .

First, by using tensor tree states (TTS) and ideas from standard mean field theory, we generalize the MPS ansatz to higher dimensions. We employ the time-dependent-variational-principle to analytically calculate the equations of motion for lattices of arbitrary connectivity. We find that the coherent oscillations in the quantum system are associated to stable periodic orbits in a mixed phase space. This method provides a new way to identify entangled states which display coherent dynamics. Finally, we associate slowly thermalizing states to regular "islands" in the mixed phase space.

DY 19.3 Tue 10:00 HSZ 204

Collective behavior of an excitonic insulator in the quantum electromagnetic field — •Katharina Lenk and Martin Eckstein — Department of Physics, University of Erlangen-Nuremnberg, 91058 Erlangen, Germany

The strong coupling of light and matter in cavity quantum electrodynamics provides new avenues to engineer properties of complex materials. In this talk, we investigate the behavior of a so-called excitonic insulator (EI) in a cavity. The EI is a phase driven by the Coulomb interaction, in which two bands of a semiconductor or semimetal spontaneously hybridize, leading to the opening of a gap. We consider the particular case in which the EI implies a breaking of the U(1) symmetry related to the conservation of charge in the individual bands. The coupling of a generic bosonic mode, such as the coordinate of a phonon, reduces the symmetry, adds a mass to the phase mode, and stabilizes the symmetry-broken phase. While this suggests that a similar mechanism may be at work for the coupling of the EI to a cavity mode, we show that the balancing of dipolar interactions and the dipolar light-matter coupling leaves the phase mode massless, in spite of the breaking of the U(1) symmetry.

DY 19.4 Tue 10:15 HSZ 204

A memory truncation scheme to investigate long-time dynamics in correlated systems — •Antonio Picano and Martin Eckstein — Friedrich-Alexander-Universität Erlangen-Nürnberg

We present an approach to follow the evolution of many-body systems up to previously unaccessible long time scales. Provided only that the system of interest shows a self-energy that is short-range in time, its time evolution can be determined by solving a simplified version of the full Kadanoff-Baym equations. The computational effort scales only linearly with the number of time-steps, and the computer memory is independent of the propagation time.

We have applied the method to investigate the dynamical phase transitions from antiferromagnetic to paramagnetic states driven by an interaction quench in the fermionic Hubbard model, using the nonequilibrium dynamical mean-field theory. We have observed the presence of two dynamical transition points: one is related to the thermal phase transition, the other is connected to the existence of a transient nonthermal antiferromagnetic order above the thermal critical temperature. The non-thermal order displays a slow decay, which is followed by a faster thermalization process, and thermalization is significantly delayed by the trapping of the system in the nonthermal state.

DY 19.5 Tue 10:30 HSZ 204

Critical quenches in the attractive Hubbard model — •Christopher Stahl and Martin Eckstein — Lehrstuhl für Theoretische Festkörperphysik, FAU Erlangen-Nürnberg, Deutschland

We investigate critical quenches from a paramagnetic phase in a three dimensional attractive Hubbard model towards the ordered superconducting phase using a two-time Green's function formalism on the Keldysh contour and the fluctuation exchange approximation (FLEX). This self-consistent approach gives access to the coupled dynamics of single particle properties and collective fluctuations in the transient state, and allows to study the growth of order in the initially disordered system. By truncating the two-time self-energy with respect to relative time we set up a long-time multi-scale simulation which resolves the dynamics of both the fast electronic and slow bosonic degrees of freedom. This may help to close the gap between short time microscopic simulations and predictions for the long time behavior based on Ginzburg-Landau-theory and the theory of dynamic critical phenomena.

DY 19.6 Tue 10:45 HSZ 204

Thermalization of a two-species condensate — •Jan Louw[1], Michael Kastner[2], and Johannes Kriel[2] — [1]University of Goettingen, Goettingen, Germany — [2]Stellenbosch University, Stellenbosch, South Africa

Motivated by recent experiments, we study the time evolution of a two-species Bose-Einstein condensate which is coupled to a bosonic bath. For the particular condensate, unconventional thermodynamics have recently been predicted. To study these thermal properties we find the conditions under which this open quantum system thermalizes—equilibrates to the Gibbs state describing the canonical ensemble. We do this in a semi-classical picture with corrections scaling with the inverse system size.

DY 19.7 Tue 11:00 HSZ 204

Exceptional points and the topology of quantum many-body spectra — •David Luitz and Francesco Piazza — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

We show that in a generic, ergodic quantum many-body system the interactions induce a nontrivial topology for an arbitrarily small non-Hermitian component of the Hamiltonian. This is due to an exponential-in-system-size proliferation of exceptional points which have the Hermitian limit as an accumulation (hyper)surface. The nearest-neighbor level repulsion characterizing Hermitian ergodic many-body systems is thus shown to be a projection of a richer phenomenology, where actually all the exponentially many eigenvalues are pairwise connected in a topologically robust fashion via exceptional points.

15 min. break.

DY 19.8 Tue 11:30 HSZ 204

η–paired hidden phase in photodoped Mott insulators — •Jiajun Li[1], Denis Golez[2], Philipp Werner[3], and Martin Eckstein[1] — [1]University of Erlangen-Nuremberg, Germany — [2]Flatiron Institute, New York, US — [3]University of Fribourg, Switzerland

We show that a metastable η–pairing superconducting phase can be induced by photodoping doublons and holes into a strongly repulsive fermionic Hubbard model. The doublon-hole condensate extends over a wide range of doublon densities and effective temperatures. Different non-equilibrium protocols to realize this state are proposed and numerically tested. We also study the optical conductivity in the superconducting phase, which exhibits ideal metallic behavior, i.e., a delta function at zero-frequency in the conductivity, in conjunction with negative conductivity at large frequencies. These characteristic optical properties can provide a fingerprint of the η-pairing phase in pump-probe experiments.

DY 19.9 Tue 11:45 HSZ 204

η-pairing in one-dimensional Mott insulators — •Satoshi Ejima[1], Tatsuya Kaneko[2], Florian Lange[1], Seiji Yunoki[3,4,5], and Holger Fehske[1] — [1]Institute of Physics, University Greifswald, Greifswald, Germany — [2]Department of Physics, Columbia University, New York NY, USA — [3]RIKEN Cluster for Pioneering Research, Wako, Japan — [4]RIKEN Center for Emergent Matter Science, Wako, Japan — [5]RIKEN Center for Computational Science, Kobe, Japan

Very recently, it was theoretically demonstrated that unconventional superconductivity correlation can be induced by pulse irradiation in the simple Mott insulator of the half-filled Hubbard model [1]. This superconducting-like state stems from the so-called η-pairing mechanism, characterized by staggered pair-density-wave oscillations of the off-diagonal correlations.

In this study, we first explore precisely under which conditions the η-pairing state appears most pronouncedly at zero temperature by means of the time-dependent density-matrix renormalization group (DMRG) method in the matrix-product-state representation. Carrying out temperature-dependent DMRG in combination with the purification technique, we furthermore prove whether this state can survive at finite temperatures, in order to check the possible experimental observation of the pairing state, e.g., in optical lattices.

[1] T. Kaneko, T. Shirakawa, S. Sorella and S. Yunoki, Phys. Rev. Lett. **122**, 077002 (2019).

DY 19.10 Tue 12:00 HSZ 204

Effect of dimensionality on the dynamics of optically excited Mott-Hubbard clusters — •Junichi Okamoto — Institute of Physics, University of Freiburg, Freiburg, Germany

Development of intense light sources and of various time-resolved spectroscopies has opened up a new avenue in condensed matter physics. In particular, optically excited nonequilibrium states of strongly correlated systems show nontrivial and intriguing phenomena such as light-induced superconductivity or ultrafast structural switching. An important step to understand these phenomena is to investigate the excitation spectrum of a system. To this end, we use an exact diagonalization method to study the effect of dimensionality on the dynamics of optically excited states in Mott-Hubbard clusters. We compare the excitation spectrum in one and two dimensions, and demonstrate the different transient dynamics induced by short optical pulses.

DY 19.11 Tue 12:15 HSZ 204

Disentangling sources of quantum entanglement in quench dynamics — •Lorenzo Pastori[1], Markus Heyl[2], and Jan Carl Budich[1] — [1]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Quantum entanglement may have various origins ranging from solely interaction-driven quantum correlations to single-particle effects. Here, we explore the dependence of entanglement on time-dependent single-particle basis transformations in fermionic quantum many-body systems, thus aiming at isolating single-particle sources of entanglement growth in quench dynamics. Using exact diagonalization methods, for paradigmatic nonintegrable models we compare to the standard real-space cut various physically motivated bipartitions. Moreover, we search for a minimal entanglement basis using local optimization algorithms, which at short to intermediate postquench times yields a significant reduction of entanglement beyond a dynamical Hartree-Fock solution. In the long-time limit, we identify an asymptotic universality of entanglement for weakly interacting systems, as well as a crossover from dominant real-space to momentum-space entanglement in Hubbard models undergoing an interaction quench. Finally, we discuss the relevance of our findings for the development of tensor-network based algorithms for quantum dynamics.

DY 19.12 Tue 12:30 HSZ 204

Statistical localization: from strong fragmentation to strong edge modes — •Tibor Rakovszky[1], Pablo Sala[1], Ruben Verresen[2], Michael Knap[1], and Frank Pollmann[1] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Department of Physics, Harvard University, Cambridge, MA 02138, USA

Certain disorder-free Hamiltonians can be non-ergodic due to a strong fragmentation of the Hilbert space into disconnected sectors. Here, we characterize such systems by introducing the notion of "statistically localized integrals of motion" (SLIOM), whose eigenvalues label the connected components of the Hilbert space. SLIOMs are not spatially localized in the operator sense, but appear localized to sub-extensive regions when their expectation value is taken in typical states with a finite density of particles. We illustrate this general concept on several Hamiltonians, both with and without dipole conservation. Furthermore, we demonstrate that there exist perturbations which destroy these integrals of motion in the bulk of the system, while keeping them on the boundary. This results in statistically localized strong zero modes, leading to infinitely long-lived edge magnetizations along with a thermalizing bulk, constituting the first example of such strong edge modes in a non-integrable model. We also show that in a particular example, these edge modes lead to the appearance of topological string order in a certain subset of highly excited eigenstates. Some of our suggested models can be realized in Rydberg quantum simulators.

DY 19.13 Tue 12:45 HSZ 204

Matrix product state investigations of time-dependent spectral functions after a photoexcitation — •Constantin Meyer and Salvatore R. Manmana — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

We study the time-dependent dynamical structure factor after a photoexcitation of a variant of the 1d Hubbard model with a background staggered magnetic field using matrix product state (MPS) techniques. In particular, we use the time-dependent variational principle (TDVP) to investigate the time evolution of the band population, which is a quantity accessible to time-resolved ARPES experiments. Different scenarios for the photoexcitations are discussed, e.g., Peierls-substitution or direct excitation in k-space. Using MPS, we can study in detail the effect of the electron-electron interaction on the redistribution of the band populations in the various photoexcitation setups. An outlook to the relevance of electron-electron interactions on light-harvesting mechanisms in correlated materials is given.

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