TT 38: Nonequilibrium Quantum Many-Body Systems II (joint session TT/DY)

Time: Wednesday 15:00–18:30 Location: HSZ 204

TT 38.1 Wed 15:00 HSZ 204

Hilbert space fragmentation in open quantum systems — •Yahui Li, Pablo Sala, and Frank Pollmann — Department of Physics, TFK, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany

Several mechanisms have been identified that can lead to a breakdown of thermalization in closed quantum systems-including integrability and many-body localization. Recently, a novel mechanism for ergodicity breaking has been discovered in systems with certain dynamical constraints, where the Hilbert space fragments into exponentially many disconnected subspaces. An open question is how such systems evolve when they are coupled to a dissipative bath.

We find that the Hilbert space fragmentation can be utilized to preserve coherence in the presence of dissipation. We study a quantum fragmented model, which fragments in an entangled basis due to unconventional non-Abelian symmetries. We investigate the Lindblad dynamics under two different couplings, which either preserves or destroys the quantum fragmentation structure. At sufficiently large couplings, the operator space entanglement is suppressed, which allows for an efficient numerical simulation using tensor networks. Surprisingly, under the structure-preserving noise, we observe finite Renyi negativity, indicating non-vanishing quantum correlations. Using an analytic approach, we derive the stationary states under both couplings, which explains the long-time behaviors observed in numerical simulations.

TT 38.2 Wed 15:15 HSZ 204

Hilbert space fragmentation and interaction-induced localization in the extended Fermi-Hubbard model — •Philipp Frey, Lucas Hackl, and Stephan Rachel — University of Melbourne

We study Hilbert space fragmentation in the extended Fermi-Hubbard model with nearest and next-nearest neighbor interactions. Using a generalized spin/mover picture and saddle point methods, we derive lower bounds for the scaling of the number of frozen states and for the size of the largest block preserved under the dynamics. We find fragmentation for strong nearest and next-nearest neighbor repulsions as well as for the combined case. Our results suggest that the involvement of next-nearest neighbor repulsions leads to an increased tendency for localization. We then model the dynamics for larger systems using Markov simulations to test these findings and unveil in which interaction regimes the dynamics becomes spatially localized. In particular, we show that for strong nearest and next-nearest neighbor interactions random initial states will localize provided that the density of initial movers is sufficiently low.

[1] arXiv:2209.11777 (accepted for publication in PRB Letter)

TT 38.3 Wed 15:30 HSZ 204

Rate functions and the approach to adiabaticity in quantum many body systems — •Vibhu Mishra, Salvatore Manmana, and Stefan Kehrein — Institute for Theoretical Physics, Georg-August-Universität Goettingen, Friedrich-Hund-Platz 1, 37077 Goettingen

The quantum adiabatic theorem is a fundamental result in quantum mechanics with applications ranging from quantum adiabatic computation to topological systems, while also serving as a theoretical foundation to many body perturbation theory via the Gell-Mann Low theorem.

We establish an inherent competition between ramp times T for an adiabatic process vs the system size N, in the behavior of relevant many body overlaps. We study this interplay between T and N by analyzing the properties of rate functions which are defined to be intensive quantities that give us a quantitative measure of the deviation from adiabaticity in the thermodynamic limit.

We analyze the Transverse Field Ising Model and the XXZ chain in $1D$ using exact diagonalization. We find that the rate functions show algebraic decay with increasing ramp time T. The decay exponent of the rate function for ramps within the gapped phase is 2, for ramps across Ising critical point it is 0.5 and within the Luttinger Liquid phase it is 1. The immediate implication is that the many body adiabatic time scales grow unavoidably with system size, namely as the $\sqrt{N}$ for ramps within the gapped phase, and with N within the Luttinger Liquid phase.

TT 38.4 Wed 15:45 HSZ 204

Classical route to ergodicity and scarring phenomena in a two-component Bose-Josephson junction — Debabrata Mondal[1], Sudip Sinha[1], •Sayak Ray[2], Johann Kroha[2], and Subhasis Sinha[1] — [1]Indian Institute of Science Education and Research Kolkata, Mohanpur, Nadia 741246, India — [2]Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Nußallee 12, 53115 Bonn, Germany

We consider a Bose-Josephson junction (BJJ) formed by the binary mixture of ultracold atoms to investigate the manifestation of coherent collective dynamics on ergodicity and quantum scars, unfolding the connection between them. By tuning the inter and intra-species interaction, we demonstrate a rich variety of Josephson dynamics and transitions between them, which plays a crucial role in controlling the overall ergodic behaviour. The signature of underlying classicality is revealed from the entanglement spectrum, which also elucidates the formation of quantum scars of unstable steady states and of periodic orbits leading to athermal behaviour in a reduced Hilbert space. We show how the degree of ergodicity across the energy band and the scarring phenomena can be probed from the auto-correlation function as well from the phase fluctuation of the condensates, which has relevance in cold atom experiments. The model can also be realized in spin systems with application to information processing and lattice-gauge simulation.

[1] D. Mondal, S. Sinha, S. Ray, J. Kroha, and S. Sinha, Phys. Rev. A **106**, 043321 (2022)

TT 38.5 Wed 16:00 HSZ 204

Ultrafast dynamics of cold Fermi gas after a local quench — Nikolay Gnezdilov[1], •Andrei Pavlov[2,3], Vladimir Ohanesjan[4], Yevheniia Cheipesh[4], and Koenraad Schalm[4] — [1]Department of Physics, University of Florida, Gainesville, USA — [2]The Abdus Salam International Centre for Theoretical Physics (ICTP) Strada Costiera 11, Trieste, Italy — [3]Institut für QuantenMaterialien und Technologien, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, Eggenstein-Leopoldshafen, Germany — [4]Instituut-Lorentz, Universiteit Leiden, Leiden, The Netherlands

We consider energy dynamics of two initially independent reservoirs A and B filled with a cold Fermi gas coupled and decoupled by two quantum quenches following one another. The energy change in the system adds up the heat transferred between A and B and the work done by the quench to uncouple the reservoirs. In case when A and B interact for a short time, we find an energy increase in both reservoirs upon decoupling. This energy gain results from the quenches' work and does not depend on the initial temperature imbalance between the reservoirs. We relate the quenches' work to the mutual correlations of A and B expressed through their von Neumann entropies. Utilizing this relation, we show that once A and B become coupled, their von Neumann entropies grow (on a timescale of the Fermi time) faster than thermal transport within the system. For a metallic setup, this implies the characteristic timescale of correlations' growth to be in the femtosecond range, while for the ultracold atoms, we expect it to be in the millisecond range.

TT 38.6 Wed 16:15 HSZ 204

A conjecture regarding the overlap of different ground states within the same phase — •Sarah Damerow and Stefan Kehrein — Georg-August Universität Göttingen

An extension of the adiabatic theorem to quantum quenches, i.e. non-adiabatic changes, is presented. Using exact diagonalisation, we numerically study the Transverse Field Ising Model (TFIM) and the Axial Next Nearest Neighbour Ising Model (ANNNI). We numerically test the following conjecture: Within the same phase, the overlap between the initial ground state and the ground state of the quenched Hamiltonian is the largest possible eigenstate overlap. In the TFIM, this conjecture is confirmed for both the paramagnetic (PM) and the ferromagnetic (FM) phases. In the ANNNI model results are ambiguous in some phases, due to both numerical errors and finite size effects.

15 min. break

TT 38.7 Wed 16:45 HSZ 204

Charge, spin, and heat shot noises in the absence of average currents — •Ludovico Tesser, Matteo Acciai, Christian Spånslätt, Juliette Monsel, and Janine Splettstoesser — Chalmers University of Technology, Gothenburg, Sweden

Shot noise in electronic conductors occurs when the system is brought out of equilibrium, e.g., by a stationary bias. However, nonequilibrium does not imply that an average current flows. Indeed, the situation where selected currents are suppressed is of interest in fields like thermoelectrics and spintronics, raising the question of how the related noises behave.

I will present results on zero-current charge, spin, and heat noises in two-terminal mesoscopic conductors induced by voltage, spin and temperature biases. The nonequilibrium shot noises can be arbitrarily large, even if the respective average currents vanish. However, as soon as a temperature bias is present, additional equilibrium (thermal-like) noise necessarily occurs. This equilibrium noise sets an upper bound on the zero-current nonequilibrium charge and spin shot noise [1,2]. We have shown that the bound on the charge noise for strictly two-terminal conductors even extends into the finite-frequency regime. By contrast, these bounds can be overcome for heat transport by breaking the spin and electron-hole symmetries, respectively.

[1] J. Eriksson, M. Acciai, L. Tesser, J. Splettstoesser, Phys. Rev. Lett. 127, 136801 (2021)
[2] L. Tesser, M. Acciai, C. Spånslätt, J. Monsel, J. Splettstoesser, arXiv:2210.06051 [cond-mat.mes-hall] (2022)

TT 38.8 Wed 17:00 HSZ 204

Maximally chaotic to Fermi liquid crossover in a generalized SYK model — •Nick von Selzam and Stefan Kehrein — Institute for Theoretical Physics, University of Göttingen, Germany

We consider a generalized Sachdev-Ye-Kitaev (SYK) model: Majorana fermions on $\mathcal{N}$ sites with random $\frac{q}{2}$-body all to all interactions plus a kinetic energy term.

The SYK model can be seen as a toy model for quantum chaos and does not allow for a quasiparticle description. We discuss the continuous crossover between the Fermi liquid regime, dominated by the kinetic term, and the maximally chaotic regime, dominated by the SYK interaction, by studying the quantum Lyapunov exponents.

For fixed interaction strength there exists a crossover temperature for which the Lyapunov exponent becomes maximal. For lower temperatures the Lyapunov exponent is exponentially small. For larger temperatures the behaviour is close to indistinguishable from the pure SYK term.

TT 38.9 Wed 17:15 HSZ 204

Vibrationally-coupled electron transport in a quantum shuttle: A study using the hierarchical equations of motion approach — •Salvatore Gatto, Christoph Kaspar, and Michael Thoss — Institute of Physics, Albert-Ludwigs-Universität Freiburg

A quantum shuttle is an archetypical nanoelectromechanical device, in which the coupling of electronic and mechanical degrees of freedom is crucial [1]. In this contribution, we investigate transport properties of quantum shuttles, with a particular focus to the so-called shuttling regime, in which the transport of electrons is synchronized with the mechanical motion. The transport characteristics are strongly influenced by the interplay of electronic and vibrational degrees of freedom, which manifests itself in step structures of the current-voltage characteristics. An effective molecule-lead coupling results in an increase of the current with respect to the tunneling regime. The study uses the hierarchical equations of motion approach, which allows a numerically exact simulation of nonequilibrium transport in general open quantum systems involving multiple bosonic and fermionic environments [2].

[1] Novotný et al., Phys. Rev. Lett. 92, 248302 (2004)
[2] J. Bätge, Y. Ke, C. Kaspar, and M. Thoss, Phys. Rev. B 103, 235413 (2021)

TT 38.10 Wed 17:30 HSZ 204

Effective form factors for finite temperature correlation functions — •Oleksandr Gamayun — University of Warsaw, ul. Pasteura 5, 02-093 Warsaw, Poland

The behavior of dynamical correlation functions in one-dimensional quantum systems at zero temperature is now very well understood in terms of linear and non-linear Luttinger models. The "microscopic" justification of these models consists in exactly accounting for the soft-mode excitations around the vacuum state and at most few high-energy excitations. At finite temperature, or more generically for finite entropy states, this direct approach is not strictly applicable due to the different structure of soft excitations. To address these issues we study the asymptotic behavior of correlation functions in one-dimensional free fermion models. On the one hand, we obtain exact answers in terms of Fredholm determinants. On the other hand, based on "microscopic" resummations, we develop a phenomenological approach that introduces the effective form factors and reduces the problem to the zero temperature case. The information about the initial state is transferred into the scattering phase of the effective fermions. I will demonstrate how this works for correlation functions in the XY model, mobile impurity, and the sine-kernel Fredholm determinants.

TT 38.11 Wed 17:45 HSZ 204

Transfer-matrix summation of path integrals for transport through nanostructures — Simon Mundinar, •Alexander Hahn, Jürgen König, and Alfred Hucht — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

On the basis of the method of iterative summation of path integrals (ISPI), we develop a numerically exact transfer-matrix method to describe the nonequilibrium properties of interacting quantum-dot systems. For this, we map the ISPI scheme to a transfer-matrix approach [1], which is more accessible to physical interpretation, allows for a more transparent formulation of the theory, and substantially improves the efficiency. In particular, the stationary limit is directly implemented, without the need of extrapolation. The resulting new method, referred to as "Transfer-matrix Summation of Path Integrals" (TraSPI), is then applied to resonant electronic transport through a single-level quantum dot [2].

[1] S. Mundinar, P. Stegmann, J. König, and S. Weiss, Phys. Rev. B **99**, 195457 (2019)
[2] S. Mundinar, A. Hahn, J. König, and A. Hucht, Phys. Rev. B **106**, 165427 (2022)

TT 38.12 Wed 18:00 HSZ 204

Quasi-particle excitations at Mott-metal interfaces — •Jan Verlage[1], Friedemann Queisser[2,3], Peter Kratzer[1], and Ralf Schützhold[2,3] — [1]Fakultät für Physik, Universität Duisburg-Essen — [2]Institut für Theoretische Physik, Helmholtz-Zentrum Dresden-Rossendorf — [3]Institut für Theoretische Physik, Technische Universität Dresden

We investigate excitations at the interface between a metallic bulk and a strongly correlated Mott insulator. Employing a hierarchy of correlations we identify effective quasi-particle and hole excitations in the heterostructure. To leading order in the hierarchy, the modes satisfy an effective two-component evolution equation. This allows the investigation of evanescent modes at the interface and tunneling through a Mott insulating layer.

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TT 38.13 Wed 18:15 HSZ 204

Configuration interaction based nonequilibrium steady state impurity solver — •Daniel Werner, Jan Lotze, and Enrico Arrigoni — ITPCP, Graz, Austria

We present a solver for correlated impurity problems out of equilibrium based on a combination of the so-called auxiliary master equation approach (AMEA) and the configuration interaction (CI) expansion. Within AMEA one maps the original impurity model onto an auxiliary open quantum system with a restricted number of bath sites which can be addressed by numerical many-body approaches such as ED or MPS. While the mapping becomes exponentially more accurate with increasing number of bath sites, ED implementations are severely limited due to the fast increase of the Hilbert space dimension for open systems, and the MPS solver typically requires rather long runtimes. Here, we propose to adopt a CI approach to solve numerically the correlated auxiliary open quantum system. This allows access to a larger number of bath sites at lower computational costs than for ED. We benchmark the approach with NRG results in equilibrium and with MPS out of equilibrium. We evaluate the current, the conductance as well as the Kondo peak and its splitting. We obtain a rather accurate scaling of the conductance as a function of the bias voltage and temperature rescaled by TK for moderate to strong interactions in a wide range of parameters. The approach combines the fast runtime of ED with an accuracy close to the one achieved by MPS making it an attractive solver for nonequilibrium DMFT. (arXiv: 2210.09623)