DY 6: Dynamics in many-body systems: Equilibration and localization I (joint session DY/TT)

Time: Monday 10:00–13:00 Location: H19

DY 6.1 Mon 10:00 H19

Modern Principles of Equilibration in Closed Quantum Systems do Not Rule Out Strange Relaxation Dynamics — Lars Knipschild and •Jochen Gemmer — Universität Osnabrück, Germany

The quest for equilibration and thermalization in closed quantum systems has stimulated vast scientific effort, especially in the last decades. Various principles and approaches have been put forth, such as the eigenstate thermalization hypothesis, quantum chaos, typicality, the non-resonance principle, the unfeasibility of fine-tuned initial states, etc. While these approaches are well suited to explain that observables will assume specific "equilibrium" values for most points in time in between some initial time and a very distant future, they do not address the concrete dynamics towards these values. Furthermore they do not rule out substantial observable revivals on relevant timescales . We demonstrate that indeed very unexpected dynamics may result for systems and observables complying with all the above principles. This occurs for a very large set of non-fine tuned initial states.

DY 6.2 Mon 10:15 H19

Entanglement-ergodic quantum systems equilibrate exponentially well — Henrik Wilming[1], •Marcel Goihl[2], Ingo Roth[2], and Jens Eisert[2] — [1]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany

One of the outstanding problems in non-equilibrium physics is to precisely understand when and how physically relevant observables in many-body systems equilibrate under unitary time evolution. General equilibration results have been proven that show that equilibration is generic provided that the initial state has overlap with sufficiently many energy levels and the energy spectrum is sufficiently generic. At the same time results showing that natural initial states fulfill this condition are lacking. We present stringent results for equilibration of lattice systems in which the amount of entanglement in energy eigenstates with finite energy density is extensive for some subset of the lattice. Concretely, we carefully formalize a notion of "entanglement-ergodicity" in terms of Rényi entropies and derive that systems fulfilling this condition equilibrate exponentially well. Our proof uses insights about Rényi entropies and combines them with recent results about the probability distribution of energy in local lattice systems with initial states that are weakly correlated.

DY 6.3 Mon 10:30 H19

Out-Of-Time-Ordered Correlators in critical systems - Instability and the onset of chaos — •Dominik Hahn, Benjamin Geiger, Quirin Hummel, and Klaus Richter — Universität Regensburg

It is known from mean field theory that a system of bosons with attractive contact interaction in one dimension exhibits a quantum phase transition at a certain critical coupling. This transition has its manifestation in the formation of a local instability in the integrable mean-field dynamics. By adding an external potential, we investigate the transition from integrability to chaos in this system. A characteristic feature of chaotic motion, the exponential sensitivity to initial conditions, can be also detected in the corresponding quantum mechanical system using Out-Of-Time-Ordered Correlators (OTOCs). It can be shown, that a local instability is sufficient to generate an exponential growth of certain OTOCs. After breaking the integrability, we find evidence, that the OTOC growth is affected by an additional exponent, which can be related to the largest Lyapunov exponent of the system.

DY 6.4 Mon 10:45 H19

Thermalization and eigenstate thermalization hypothesis in the Holstein polaron model — David Jansen[1], •Jan Stolpp[2], Lev Vidmar[3], and Fabian Heidrich-Meisner[2] — [1]Arnold-Sommerfeld-Center for Theoretical Physics, LMU Munich — [2]Institute for Theoretical Physics, University of Göttingen — [3]Jozef Stefan Institute, Ljubljana

The 1d Holstein model is a paradigmatic system to study polaron physics and the nonequilibrium dynamics of charge carriers coupled to phonons. While the electronic relaxation dynamics of a single charge carrier is a much studied topic (see, e.g. [1]), here, we systematically investigate whether the 1d Holstein model in the single-polaron limit is ergodic by checking the criteria of the eigenstate thermalization hypothesis and by testing for established quantum chaos indicators. Using exact diagonalization techniques we find that the level spacing distribution is Wigner-Dyson, which is characteristic for a quantum chaotic system. Remarkably, both the diagonal and offdiagonal matrix elements of typical observables obey properties predicted by the eigenstate thermalization hypothesis. Thus, we found an example in which the coupling term between the electronic and phononic subspaces leads to ergodic behavior, even though the phonon system itself consists of uncoupled, local harmonic oscillators.

[1] Phys. Rev. B 91, 104302 (2015)

DY 6.5 Mon 11:00 H19

Bounds on equilibration time scales — •Robin Heveling, Lars Knipschild, and Jochen Gemmer — University of Osnabrueck, Osnabrueck, Germany

We consider closed quantum systems consisting of a single system-spin and a spin-bath. Starting from a product state of a microcanonical bath at some energy and a fully aligned system-spin, equilibration time scales of the magnetization are calculated for various coupling strengths. The paper PRX 7, 031027 (2017) conjectures a relation between short time behaviour and long equilibration time scales. We probe this conjecture. For small couplings, we find exponential relaxation to an equilibrium value. The exponential nature of the decay may break down at some point when decreasing the coupling strength.

DY 6.6 Mon 11:15 H19

Decoherence Entails Exponential Forgetting in Systems Complying with the Eigenstate Thermalization Hypothesis — •Lars Knipschild and Jochen Gemmer — University of Osnabrück, D-49069 Osnabrück, Germany

According to the eigenstate thermalization ansatz, matrices representing generic few-body observables exhibit a specific form when displayed regarding the eigenbasis of the Hamiltonian. We examine the effect of environmental induced decoherence on the expectation value dynamics of observables confirming with said eigenstate thermalization ansatz. We find that this influence is equivalent to an exponential damping of the memory-kernel appearing in an equation of motion for the expectation value. The statement is formulated as a rigorous theorem.

15 min. break

DY 6.7 Mon 11:45 H19

Many body localized system weakly coupled to thermal environment — •Ling-Na Wu, Alexander Schnell, Giuseppe De Tomasi, Markus Heyl, and André Eckardt — Max Planck Institute for the Physics of Complex Systems

Many body localization (MBL), which describes the failing of an interacting system under disorder to reach thermalization, has attracted widespread attentions. In recent years, the imperfect experimental environment has excited an intense interest in the effect of dissipations on MBL. We formulate an efficient method for the description of MBL systems in weak contact with thermal environments at temperature T. As an example, we study the transport property of a fermion Hubbard chain coupled to a thermal bath and recover a conductivity following Mott's law for variable range hopping. Weak attractive (repulsive) interactions are found to enhance (decrease) the transport, which is attributed to an interaction-induced modification of the density of states due to spatio-energetic correlations. We also study the effect of dissipations on disorder-free localized system and compare it with the conventional disorder-induced localized system.

DY 6.8 Mon 12:00 H19

Many-body localization and delocalization in large quantum chains — •Elmer V. H. Doggen[1], Frank Schindler[2], Konstantin S. Tikhonov[1,3], Alexander D. Mirlin[1,3,4,5], Titus Neupert[2], Dmitry G. Polyakov[1], and Igor V. Gornyi[1,3,4,6] — [1]Institut für Nanotechnologie, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [2]Department of Physics, University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland — [3]L. D. Landau Institute for Theoretical Physics RAS, 119334 Moscow, Russia

— [4]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [5]Petersburg Nuclear Physics Institute, 188300 St. Petersburg, Russia — [6]A. F. Ioffe Physico-Technical Institute, 194021 St. Petersburg, Russia

We theoretically study the quench dynamics for an isolated Heisenberg spin chain with a random on-site magnetic field, which is one of the paradigmatic models of a many-body localization transition. We use the time-dependent variational principle as applied to matrix product states, which allows us to controllably study chains of a length up to L=100 spins. We find that the consideration of the larger system sizes substantially increases the estimate for the critical disorder that separates the ergodic and many-body localized regimes, compared to the values in the literature. From a technical perspective, we develop an adaptation of the "learning by confusion" machine-learning approach that can determine the critical disorder.

DY 6.9 Mon 12:15 H19

Detection and characterization of many-body localization in central spin models — •Daniel Hetterich[1,4], Norman Yao[2], Maksym Serbyn[3], Frank Pollmann[4], and Björn Trauzettel[1] — [1]Institute for theoretical Physics, University of Würzburg — [2]Department of Physics, University of California, Berkeley — [3]Insitute of Science and Technology, Wien — [4]Department of Physics, Technical University Munich

We analyze a disordered central spin model, where a central spin interacts equally with each spin in a periodic one-dimensional (1D) random-field Heisenberg chain. If the Heisenberg chain is initially in the many-body localized (MBL) phase, we find that the coupling to the central spin suffices to delocalize the chain for a substantial range of coupling strengths. We calculate the phase diagram of the model and identify the phase boundary between the MBL and ergodic phase. Within the localized phase, the central spin significantly enhances the rate of the logarithmic entanglement growth and its saturation value. We attribute the increase in entanglement entropy to a nonextensive enhancement of magnetization fluctuations induced by the central spin. Finally, we demonstrate that correlation functions of the central spin can be utilized to distinguish between MBL and ergodic phases of the 1D chain. Hence, we propose the use of a central spin as a possible experimental probe to identify the MBL phase.

DY 6.10 Mon 12:30 H19

Magnetization and Entanglement after a geometric quench in the XXZ chain — •Matthias Gruber and Viktor Eisler — TU Graz, Graz, Österreich

We consider the XXZ spin chain in the gapless regime and study magnetization and entropy profiles after a geometric quench. This quench is realized by preparing the ground states with zero and maximum magnetizations on the two halves of a chain and letting it evolve subsequently. The magnetization profiles during time evolution are studied numerically by tDMRG and compared to the predictions obtained from generalized hydrodynamics (GHD). We find that the GHD description of the dynamics provides a very good agreement with the numerical data. Furthermore, entanglement entropy profiles are also studied, finding a closed form expression in the non-interacting XX case. For the general interacting case, the propagation velocities of the entropy fronts are studied both before and after the reflection from the boundaries. Finally, we also study the relationship between magnetization fluctuations and entanglement entropy.

DY 6.11 Mon 12:45 H19

Equilibration of expectation values for statically and dynamically generated initial conditions — •Christian Bartsch — Fachbereich Physik, Universität Osnabrück, Barbarastraße 7, D-49069 Osnabrück

We investigate dynamical equilibration of expectation values in closed quantum systems for realistic non-equilibrium initial states. For statically generated initial states we find that the long time expectation values depend on the initial expectation values if eigenstate thermalization is violated. An analytical expression for the deviation from the expected ensemble value is derived for small displacements from equilibrium based on linear response theory. Analogous derivations show that this deviation vanishes for dynamically generated initial states, at least within the linear response regime. Additional numerics for magnetization and energy equilibration in an asymmetric anisotropic spin-1/2-ladder illustrate the behavior beyond linear response for both cases.