THU 12: Quantum Thermalization: Contributed Session to Symposium

Time: Thursday 14:15–16:15 Location: ZHG105

THU 12.1 Thu 14:15 ZHG105

A minimal model of relaxation in isolated quantum systems — •Uwe Holm, Morgan Berkane, Anja Kuhnhold, and Andreas Buchleitner — Physikalisches Institut, Universität Freiburg, Germany

In classical thermodynamics, heat flow is commonly introduced by a thought experiment that employs two gas-filled boxes separated by a fixed wall and initially prepared with different internal energies. Subsequently, the subsystems exchange energy irreversibly, and the internal energies of both boxes equilibrate.

We introduce an analogue microscopic model consisting of two quantum particles contained in two 2D-boxes separated by a fixed wall, and isolated against the outside world. Thermal contact is realized via long-range interactions between the particles in the adjacent boxes. We numerically simulate the resulting, non-integrable two-body dynamics, with specific focus on the questions of whether and how relaxation can be witnessed already in this very minimalist setting, and whether heat, entropy and temperature can be defined consistently.

THU 12.2 Thu 14:30 ZHG105

Eigenstate Thermalization Hypothesis correlations via non-linear Hydrodynamics — •Jiaozi Wang[1], Ruchira Mishra[2], Tian-Hua Yang[3], Luca V. Delacrétaz[2], and Silvia Pappalardi[4] — [1]U Osnabrück, Germany — [2]U Chicago, USA — [3]U Princeton, USA — [4]U Köln,, Germany

The thermalizing dynamics of many-body systems is often described through the lens of the Eigenstate Thermalization Hypothesis (ETH). ETH postulates that the statistical properties of observables, when expressed in the energy eigenbasis, are described by smooth functions, that also describe correlations among the matrix elements. However, the form of these functions is usually left undetermined. In this work, we investigate the structure of such smooth functions by focusing on their Fourier transform, recently identified as free cumulants. Using non-linear hydrodynamics, we provide a prediction for the late-time behavior of time-ordered free cumulants in the thermodynamic limit. The prediction is further corroborated by large-scale numerical simulations of a non-integrable spin-1 Ising model, which exhibits diffusive transport behavior. Good agreement is observed in both infinite and finite-temperature regimes and for a collection of local observables. Our results indicate that the smooth multi-point correlation functions within the ETH framework admit a universal hydrodynamic description at low frequencies.

THU 12.3 Thu 14:45 ZHG105

Generating constraints and Hilbert space fragmentation by periodic driving — •Somsubhra Ghosh[1], Indranil Paul[2], Krishnendu Sengupta[3], and Lev Vidmar[1,4] — [1]Dept of Theoretical Physics, J. Stefan Institute, Ljubljana, Slovenia — [2]Laboratoire Materiaux et Phenomenes Quantiques, Paris, France — [3]School of Physical Sciences, Indian Association for the Cultivation of Science, Kolkata, India — [4]Dept of Physics, University of Ljubljana, Ljubljana, Slovenia

Hilbert space fragmentation (HSF) has long been proposed as a route to evade thermalization in isolated quantum systems by restricting its dynamics through the imposition of constraints. However, in equilibrium, such constraints are inserted *a priori* in the Hamiltonian of the system. In one of our earlier works, we had considered one such system and showed that such constraints can be realized through periodic driving. In this work, we generalize this idea and propose a general framework to generate such emergent constraints for a given system. We show that special drive frequencies exist where destructive interference suppresses processes which violate the constraints and thereby reinforces these constraints as emergent phenomena. Led by this insight, we suggest what kind of drive protocol might be suitable to generate a particular constraint for a given system. This result, in fact, goes beyond the purview of HSF and applies to the more general context of emergent symmetries in driven systems. As an application, we use this protocol to spatially localize quantum information in a spin-1/2 chain through HSF.

THU 12.4 Thu 15:00 ZHG105

Investigation of semiclassical simulations for Heisenberg-Langevin equations at low temperatures — •Scott Daniel Linz and Jochen Gemmer — Department of Mathematics/Computer Science/Physics, University of Osnabrück, D-49076 Osnabrück, Germany

A system of spins coupled to a bath is a traditional set-up in open quantum systems. Through Heisenberg's equation the spin dynamics can be modeled by a dynamical system. Interpreting terms as noise and non-Markovian damping one can arrive at a Heisenberg-Langevin equation. These are notoriously difficult to solve due to the dimensionality of the Hilbert space. Classical generalized Langevin equations, involving non-Markovian damping and colored noise are well understood and can be treated numerically with comparative ease. Thus, a semiclassical ansatz can be made by substituting quantum expectation values with classical functions. This allows the application of standard methods developed for classical stochastic dynamical systems to tackle spin dynamics. However, this approach is uncontrolled and should be benchmarked against known quantum dynamics. In this investigation a Hamiltonian for spin dynamics is manipulated in order to receive a set-up similar to the Weisskopf-Wigner theory of spontaneous emission in order to compare the results.

THU 12.5 Thu 15:15 ZHG105

Comprehensive analysis of electronic relaxation in one dimension Kondo lattice model — •Arturo Perez Romero, Mica Schwarm, and Fabian Heidrich-Meisner — Institut for Theoretical Physics, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany

Recent advancements in laser technology have made it possible to create non-equilibrium conditions on timescales that outpace energy exchange across a wide range of degrees of freedom. The above represents a challenge not only for condensed matter experimental physicists but also for theoretical physicists who are motivated to describe a great variety of far-from-equilibrium systems. In this paper, we study the real-time dynamics of two paradigmatic models: the Kondo lattice model (KLM) and the Kondo-Heisenberg model (KHM) in one dimension. We analyze the role of exchange couplings for the relaxation of a single charge carrier via the time-dependent Lanczos method. We conduct a comprehensive study of the time evolution by evaluating the z-spin component of the conduction electron, the local spin-spin correlation between localized and conduction electrons, the spin-spin correlation between localized spins, and the electronic momentum distribution. The study includes a comparison with statistical mechanics predictions for steady state and a study of the effect of diagonal disorder. This work was funded by the Deutsche Forschungsgemeinschaft (DPG, German Research Foundation) via CRC 1073

THU 12.6 Thu 15:30 ZHG105

Graph theory and tunable slow dynamics in quantum East Hamiltonians — •Heiko Georg Menzler[1], Mari Carmen Bañuls[2,3], and Fabian Heidrich-Meisner[1] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Max-Planck-Institut für Quantenoptik, D-85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstrasse 4, D-80799 München

We show how graph theory concepts can provide an insight into the origin of slow dynamics in systems with kinetic constraints. In particular, we observe that slow dynamics is related to the presence of strong hierarchies between nodes on the Fock-space graph in the particle occupation basis, which encodes configurations connected by a given Hamiltonian. To quantify hierarchical structures, we develop a measure of centrality of the nodes, which is applicable to generic Hamiltonian matrices and inspired by established centrality measures from graph theory. We illustrate these ideas in the quantum East (QE) model. We introduce several ways of detuning nodes in the corresponding graph that alter the hierarchical structure, defining a family of QE models. We numerically demonstrate how these detunings affect the degree of non-ergodicity on finite systems, as evidenced by both the time dependence of density autocorrelations and eigenstate properties in the detuned QE models.

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THU 12.7 Thu 15:45 ZHG105

Hierarchy of the relaxation timescales in a disordered spin-1/2 XX ladder — •Kadir Çeven, Lukas Peinemann, and Fabian Heidrich-Meisner — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Göttingen, Germany

Understanding the timescales associated with relaxation to equilibrium in closed quantum many-body systems is one of the central focuses in the study of their non-equilibrium dynamics. At late times, these relaxation processes are believed to exhibit universal behavior, emerging from the inherent randomness of chaotic Hamiltonians. In this work, we investigate a disordered spin-1/2 XX ladder—an experimentally realizable model known for its diffusive dynamics—to explore the connection between transport properties and spectral measures derived solely from the system's energy levels via these relaxation timescales.

We begin by analyzing the spectral form factor, which reveals the timescale at which the system begins to exhibit random matrix theory (RMT) statistics, known as the RMT time. We then determine the Thouless time—the time for particle to diffuse across the entire finite system—through transport analysis of the disordered model. Our numerical results confirm that, during relaxation, the RMT time occurs significantly later than the Thouless time, signalling distinct temporal regimes in the system's approach to equilibrium.

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THU 12.8 Thu 16:00 ZHG105

Observing dynamical localization on a trapped-ion qudit quantum processor — •Gonzalo Camacho — Deutsches Zentrum für Luft- und Raumfahrt (DLR), Köln, Germany

Recent impressive advances in quantum processors have opened up the possibility to witness emergent dynamical behavior in quantum many-body systems. An outstanding example is the observation of time-crystalline behavior in periodically driven systems breaking the discrete symmetry of the drive. Going beyond qubit-based architectures, in this work we use a trapped-ion qudit quantum processor to study a disorder-free, spin-1 interacting Floquet model that displays time-crystalline behavior protected by symmetry of an effective prethermal Floquet Hamiltonian. We also address the role played by multipartite entanglement in the system dynamics through the Quantum Fisher Information, which can be employed as a proxy to characterize the crossover from dynamically localized to ergodic regimes. These results pave the way for the exploration of emergent non-equilibrium phenomena in higher-dimensional quantum systems.