TT 12: Dynamics in Many-Body Systems: Interference, Equilibration and Localization I (joint session DY/TT)

Time: Monday 10:00–12:45 Location: EB 107

TT 12.1 Mon 10:00 EB 107

Post-Ehrenfest many-body quantum interferences far-out-of-equilibrium many-body systems — Steve Tomsovic[1,4], Denis Ullmo[2], Peter Schlagheck[3], •Juan-Diego Urbina[4], and Klaus Richter[4] — [1]Washington State University, USA — [2]Universite Paris Sud, France — [3]University of Liege, Belgium — [4]University of Regensburg, Germany

Many-body quantum dynamics in isolated systems far from equilibrium generate interferences beyond the Ehrenfest time where quantum and classical expectation values diverge, with recent interest in the role these interferences play in the spreading of quantum information across the many degrees of freedom[1]. We have developed a semiclassical theory which properly incorporates such quantum interference effects and showed that, for mesoscopically populated Bose-Hubbard systems, it captures post-Ehrenfest quantum phenomena very accurately even to the point to alllow for high-precision many-body spectroscopy [2].

We present here a description of this novel approach and point out how it can be used to improve the heavily used truncated Wigner method [3] by incorporating exact degenaracies of classical actions responsible of robust many-body interference effects.

[1] S. H. Shenker and D. Stanford, JHEP 3, 67 (2014).
[2] S. Tomsovic, P. Schlagheck, D. Ullmo, J. D. Urbina, and K. Richter arXiv 1711.04693 (2017).
[3] A. Sinatra, C. Lobo, and Y. Castin, J. Phys. B: Atom. Molec. Opt. Phys. 35, 3599 (2002).

TT 12.2 Mon 10:15 EB 107

Signatures of indistinguishability in bosonic many-body dynamics — Tobias Brünner[1], Gabriel Dufour[1,2], •Alberto Rodríguez[1], and Andreas Buchleitner[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, D-79104, Freiburg, Germany — [2]Freiburg Institute for Advanced Studies, Albert-Ludwigs-Universität Freiburg, Albertstraße 19, D-79104 Freiburg, Germany

Many-body interference occurs as a fundamental process during the evolution of a quantum system consisting of two or more indistinguishable particles. The (measurable) consequences of this interference, as a function of the particles' mutual indistinguishability, was studied for non-interacting photons transmitted through beam-splitter arrays. However, the role of many-body interference in the dynamics of interacting particles, e.g. cold atoms in optical lattices, had so far remained unclear. We identify a quantifier of the particles' mutual indistinguishability attuned to time-continuously evolving systems of (interacting) particles, which predicts the dynamical behaviour of observables influenced by genuine few-body interference. Our measure allows a systematic exploration of the role of many-body interference in the weakly and strongly interacting regimes.

TT 12.3 Mon 10:30 EB 107

Trajectory-based approaches for simulating nonequilibrium dynamics in open quantum systems — •Shunsuke Sato[1], Aaron Kelly[2], and Angel Rubio[1] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, DE — [2]Dalhousie University, Halifax, Canada

We present our recently developed trajectory-based quantum dynamics approach for treating nonequilibrium phenomena in electron-phonon systems. Based on a simple extension of mean field theory, this new approach leads to simulation scheme that uses a statistical ensemble of coupled trajectory pairs. The time-evolution of each pair is governed by the Euler-Lagrange variational principle. This method yields mean field theory in the limit that the trajectories are orthogonal, and in the limit that they completely overlap. Although trajectories are only coupled to a single partner, this method shows a substantial improvement over mean field theory in capturing quantum coherence in the nuclear dynamics as well as electron-nuclear correlation. The performance of our coupled trajectory method is particularly favourable in nonadiabatic systems, as it retains quantitative accuracy well beyond the perturbative electron-phonon coupling regimes of the spin-boson model, and the Holstein polaron model.

Furthermore, when utilized in tandem with the Nakajima-Zwanzig-Mori generalized quantum master equation formalism, this hybrid trajectory-based master equation approach provides an attractive route forward to a fully ab initio description of relaxation processes, such as thermalization, in condensed phase systems.

TT 12.4 Mon 10:45 EB 107

Energy transport in the driven disordered XYZ chain — •Maximilian Schulz[1,2], Scott Taylor[2], Chris Hooley[2], and Antonello Scardicchio[3,4] — [1]Max Planck Institut für Physik komplexer Systeme — [2]University of St Andrews — [3]Abdus Salam ICTP — [4]INFN, Sezione di Trieste

The delocalized region preceding the many-body localization (MBL) transition is currently receiving a significant amount of attention due to apparent deviations from typical diffusive transport. The XXZ spin chain has been shown to exhibit subdiffusive spin transport at intermediate disorder strengths, and the nature of energy transport close to the MBL transition is still a matter of debate.

We present results of a combined time-evolving block decimation and exact diagonalization study of energy currents in the disordered XYZ spin chain on the delocalized side of the MBL transition. The significance of this choice of model is that its clean hydrodynamics involves only energy currents, whereas the XXZ model has both energy and spin currents. This allows us to explore the question of how the nature of the delocalized phase depends on the hydrodynamic properties of the underlying clean model.

TT 12.5 Mon 11:00 EB 107

Construction of exact constants of motion and effective models for many-body localized systems — •Marcel Goihl, Marek Gluza, Christian Krumnow, and Jens Eisert — Dahlem Center for Complex Quantum Systems, Freie Universitat Berlin, 14195 Berlin, Germany

One of the defining features of many-body localization is the presence of extensively many quasi-local conserved quantities. These constants of motion constitute a corner-stone to an intuitive understanding of much of the phenomenology of many-body localized systems arising from effective Hamiltonians. They may be seen as local magnetization operators smeared out by a quasi-local unitary. However, to accurately identify such constants of motion remains a challenging problem. Current numerical constructions often capture the conserved operators only approximately or trade desirable properties such as exactly commuting with the Hamiltonian against each other, restricting a conclusive understanding of many-body localization. In this talk, we use methods from the theory of quantum many-body systems out of equilibrium to establish a new approach for finding a complete set of exact constants of motion which are in addition by construction guaranteed to represent Pauli-z operators. By this we are for the first time able to construct and investigate the proposed effective Hamiltonian using exact diagonalization. Hence, our work provides an important tool expected to further boost inquiries into the breakdown of transport due to quenched disorder.

15 min. break

TT 12.6 Mon 11:30 EB 107

Non-Ergodic Dynamics in Many-Body Systems — Carlo Danieli and •Sergej Flach — Center for Theoretical Physics of Complex Systems, Institute for Basic Sciences, Daejeon, Korea

Integrable models are characterized by a set of preserved actions. Close to the limits, the nonintegrable perturbations span a coupling network in action space which can be short or long ranged. The equilibrium dynamics of a system close to such limits is sensitive to the network type. Long range networks enforce ergodicity with large but finite relaxation time scales at a finite distance to the integrable limit. Short range networks lead to a loss of ergodicity at a finite distance from the limit. We demonstrate this by choosing observables which turn conserved actions at the limit. Off the limit, and fixing their value to the proper statistical average, they define manifolds in the phase space of an ergodic and equipartitioned many-body system. A typical trajectory pierces such manifolds infinitely often as time goes to infinity. Close to the integrable limit, the dynamics yields a power-law distribution of the excursion times off the manifolds. The exponent is used as a measure of distance from a potential nonergodic regime. We analyse several cases: the Fermi Pasta Ulam chain in the limit of small energies (long range network), and the Klein-Gordon, Discrete Gross Pitaevskii and coupled rotor lattices in the limit of large energies (short range network).

TT 12.7 Mon 11:45 EB 107

memory effects in the strongly anharmonic FPUT model — •Graziano Amati[1], Hugues Meyer[2], and Tanja Schilling[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, 79104 Freiburg, Germany — [2]Research Unit in Engineering Science, Université du Luxembourg, L-4364 Esch-sur-Alzette, Luxembourg

The Fermi-Pasta-Ulam-Tsingou (FPUT) Problem represents an intriguing challenge in Modern Physics. In its original formulation, it questions whether or not a Dynamical System can reach thermalization if a small anharmonicity is added to an integrable system, under specific out-of-equilibrium initial conditions. The problem was originally raised by the apparent lack of energy spreading between the normal modes of a one-dimensional chain of particles with a small anharmonicity, in case the energy at the initial time is given to the lowest frequencies of the system.

In the present work, we consider a one-dimensional chain of many particles with a strongly anharmonic interaction potential. The model is initialized at canonical equilibrium, and we take as a relevant variable the Fourier Transform of the density of particles for a tagged degree of freedom. The time correlation function of this observable exhibits an interesting non-ergodic behavior due to a temperature-driven 'FPU-like' dynamical localization, that corresponds to a nontrivial memory profile.

Via a novel coarse-graining technique, we are able to reconstruct the dynamics of the memory, and to show that the exhibited non-ergodicity can be rephrased via the memory kernel of the process.

TT 12.8 Mon 12:00 EB 107

Dynamical quantum phase transitions in the particle-antiparticle production of a lattice gauge theory — •Yi-Ping Huang and Markus Heyl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187 Dresden, Germany

Particle-antiparticle production in the presence of a static classical electric field, known as the Schwinger mechanism, represents a central physical phenomenon in gauge theories. How the particle production is affected in the quantum limit, where the backaction onto the electric field becomes essential, remains a major challenge. In this work, we study particle-antiparticle production in the quantum quench dynamics after a strong coupling of the bare particles to dynamical gauge field in a quantum link model. We find that for a strong coupling the system experiences dynamical quantum phase transitions (DQPTs) where the vacuum persistence probability (Loschmidt echo) develops non-analytic behavior at critical times. As opposed to the Schwinger mechanism, where matter fields are suddenly coupled to a classical electric field, we observe that the dynamics of the vacuum persistence probability and therefore the DQPTs cannot be understood using the classical picture of particle production. Instead, a quantum dynamical pattern emerges from the strongly coupled matter fields and dynamical gauge fields. We discuss how these findings can be experimentally observed in quantum simulators such as trapped ions.

TT 12.9 Mon 12:15 EB 107

Critical quench dynamics of random quantum spin chains — •Gergö Roosz[1,2], Yu-Cheng Lin[3], and Ferenc Igloi[2] — [1]Technische Universität Dresden — [2]MTA Wigner RCP, Hungary — [3]Graduate Institute of Applied Physics, National Chengchi University, Taipei, Taiwan

By means of free fermionic techniques combined with multiple precision arithmetic we study the time evolution of the average magnetization, $\overline{m}(t)$, of the random transverse-field Ising chain after global quenches. We observe different relaxation behaviors for quenches starting from different initial states to the critical point. Starting from a fully ordered initial state, the relaxation is logarithmically slow described by $\overline{m}(t) \sim \ln^a t$, and in a finite sample of length L the average magnetization saturates at a size-dependent plateau $\overline{m}_p(L) \sim L^{-b}$; here the two exponents satisfy the relation $b/a = \psi = 1/2$. Starting from a fully disordered initial state, the magnetization saturates to an asymptotic value $\overline{m}_p(L) \sim L^{-b'}$, with $b' \approx 1.5$. For both quenching protocols, finite-size scaling is satisfied in terms of the scaled variable $\ln t/L^{\psi}$. Furthermore, the distribution of long-time limiting values of the magnetization shows that the typical and the average values scale differently and the average is governed by rare events. The non-equilibrium dynamical behavior of the magnetization is explained through semi-classical theory.

TT 12.10 Mon 12:30 EB 107

Many-Body Localization in the Central Spin Model — •Hetterich Daniel[1], Yao Norman[2], and Trauzettel Björn[1] — [1]Institut für Theoretische Physik, Universität Würzburg, D-97074 W\"urzburg, Germany — [2]Department of Physics, University of California, Berkeley, California 94720, USA

The periodic Heisenberg chain model obeys signatures of many-body localization (MBL) that persist the insertion of a central spin, which interacts with all other spins of the periodic chain. To support this statement, we present numerical results for the level repulsion of eigenvalues and for the growth of entanglement entropy of subsystems. We discuss why under which conditions the central spin destroys the localized phase. Finally, we show that local observables that measure the central spin only serve as a MBL detector.