TT 34: Nonequilibrium Quantum Many-Body Systems 2

Time: Tuesday 14:00–16:00 Location: H22

TT 34.1 Tue 14:00 H22

Thermalization and Bose-Einstein condensation dynamics of photons coupled to a dye-molecule bath — •Michael Kajan and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

Discrete electronic or spin excitations in molecules or atoms coupled to vibrations are often described by the Jaynes-Cummings or the spin-boson models. When, in addition, the electronic excitations are coupled to the electromagnetic environment via photon emission and absorption, the system becomes not exactly solvable due to the non-canonical dynamics of the (pseudo)spins. Experimentally, by the emission of photons from a reservoir of laser-pumped dye molecules into an optical cavity with a non-zero lower band cutoff or with a discrete mode spectrum, thermalization and Bose-Einstein condensation of the photon gas has been realized [1]. We develop a novel slave boson representation for the molecule dynamics which accounts for all molecular states, electronic and vibrational, on the same footing. It makes the dynamics of photons coupled to the non-Markovian bath of molecule excitations tractable by standard diagrammatic techniques. We extend the method to describe Bose-Einstein condensation of the photons. It can be generalized in a straight-forward way to non-equilibrium time-dependent dynamics using the Keldysh technique.

[1] J. Klaers, J. Schmitt, F. Vewinger, M. Weitz, Nature **468**, 545 (2010)

TT 34.2 Tue 14:15 H22

Quantum thermalization in isolated ultracold gases — •Marvin Lenk[1], Anna Posazhennikova[2], Tim Lappe[1], and Johann Kroha[1] — [1]Physikalisches Institut, Universität Bonn, Germany — [2]Royal Holloway, University of London, United Kingdom

Quantum thermalization, i.e., how an isolated quantum system can dynamically reach thermal equilibrium behavior, is a long-standing problem of quantum statistics. The eigenstate thermalization hypothesis (ETH) poses that, under certain conditions, the long-time expectation value w.r.t. a typical energy eigenstate is indistinguishable from a microcanonical average. By contrast, thermal behavior is reached generally in a non-integrable quantum many-body system alone due to the vast size of the Hilbert space dimension D. In any realistic experiment, only a small subset of the quantum numbers defining a pure state can be measured, if D is sufficiently large. The Hilbert space spanned by the undetermined quantum numbers is traced over and dynamically forms a grand-canonical bath [Ann. Phys. **530**, 1700124 (2018)]. We identify this mechanism in a generic system of N interacting bosons in M single-particle levels by computing numerically exactly the time evolution of the reduced densitiy matrix, the entanglement entropy for the observed subsystem as well as expectation values, fluctuations, thermalization times and the distribution function. The thermalizing quantities are, thus, defined by the measurement itself and not restricted to local observables. For $N \approx 25$ and $M \approx 5$, D is large enough for thermalization to occur dynamically. By contrast, ETH requires microcanonical initial conditions implying stationary time dependence.

TT 34.3 Tue 14:30 H22

Exact long-time evolution of spinless fermion systems from a highly correlated state — •Kristof Harms, Lorenzo Cevolani, Stefan Kehrein, and Salvatore Manmana — Institute for Theoretical Physics, University of Göttingen

We investigate the dynamics of a one-dimensional system of spinless fermions, which is initially prepared in a highly correlated groundstate of an interacting Hamiltonian. In particular, for a global quench that turns off the interaction, we evolve the initial state obtained via density matrix renormalisation group (DMRG) using analytical solutions of the equations of motion. This allows us to reach arbitrary times. We examine features of the dynamics of density-density correlations and susceptibilities on several time scales. Shortly after the quench, we identify, in addition to the typical lightcone-behavior, periodic recurrences of the initial correlations outside the lightcone. At very long times, we use our approach to investigate the Fluctuation-Dissipation theorem in this strong nonequilibrium situation.

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TT 34.4 Tue 14:45 H22

Stabilizing a dissipative discrete time crystal — Leon Droenner[1], •Regina Finsterhölzl[1], Markus Heyl[2], and Alexander Carmele[1] — [1]Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany

Experimental evidence of time reversal symmetry breaking in many-body Floquet systems has led to the discovery of a new phase of matter out-of-equilibrium, the so called discrete time crystal (DTC) [1]. The DTC shows periodic oscillations with an integer number of the Floquet period. Here, an essential ingredient is random disorder such that the system is many-body localized (MBL) to remain out-of-equilibrium due to the suppression of entanglement growth within the isolated many-body system.

However, in case of an open quantum system, dissipation naturally melts the DTC [2]. To create a stable DTC in the presence of dissipation, we propose to structure the external reservoirs such that non-Markovian effects are non-negligible. Similar to MBL for the isolated system, the idea is to suppress entanglement growth with external degrees of freedom. We show that such feedback dynamics stabilize the DTC and its oscillations become independent of the coupling to the environment.

[1] J. Zhang et al, Nature 543, 217-220 (2017).
[2] A. Lazarides and R. Moessner, Phys. Rev. B 95, 195135 (2017).

TT 34.5 Tue 15:00 H22

Preparation of Floquet-topological states with shortcuts of adiabaticity — •Tobias Gulden and Netanel Lindner — Technion - Israel Institute of Technology

A major obstacle in the experimental realization of Floquet topological insulators is the preparation of the desired initial state. Fast protocols for state preparation with high fidelity are needed. We develop a modification of shortcuts to adiabaticity for Floquet systems. This allows to create a desired Floquet eigenstate out of the ground state of the undriven system within a short time. Despite crossing the topological phase transition while turning on the drive we obtain the ground state of the Floquet system with high fidelity. This approach can more generally be used in different Floquet systems.

TT 34.6 Tue 15:15 H22

Engineering Feshbach resonances by time-periodic driving — •Christoph Dauer, Axel Pelster, and Sebastian Eggert — Physics Department and Research Centre OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger Straße 46, 67663 Kaiserslautern, Germany

Magnetic Feshbach resonances are a powerful tool in order to control the scattering length in ultracold gas experiments [1], but are limited to given atomic species or applied magnetic field strengths. Here we investigate a periodically driven two-channel model describing magnetic Feshbach resonances using the Floquet formalism [2-4]. Position and width of the resulting resonances, which appear in the scattering length, turn out to be tunable by both driving strength and frequency. An extension of our two-channel model also allows to describe the corresponding case of an optical Feshbach resonance [5], where either the Rabi frequency or the detuning is modulated periodically in time. The goal of these investigations is to check whether the variability of the accessible s-wave scattering lengths can be increased by the time-periodic modulation.

[1] C. Chin et al. Rev. Mod. Phys. 82 1225 (2010)
[2] D.H. Smith. Phys. Rev. Lett. 115, 193002 (2015)
[3] A.G. Sykes, H. Landa, and D.S. Petrov. PRA 95, 062705 (2017)
[4] S.A. Reyes et al. New J. Phys. 19, 043029 (2017)
[5] O. Thomas et al. Nature Comm. 9, 2238 (2018)

TT 34.7 Tue 15:30 H22

Exploring in the dynamical quantum phase transition theory the presence of a quantum critical region close to the critical time — •Daniele Trapin and Markus Heyl — Max Planck Institute for the Physics of Complex Systems Nöthnitzer Straße 38 D-01187 Dresden

The presence of dynamical quantum phase transitions(DQPTs) with properties resembling those of the continuous phase transitions, suggests to investigate the existence of a quantum critical region in the proximity of the critical time. This region plays a fundamental role in the theory of quantum phase transition, since it allows to prove experimentally the presence of the quantum critical point. This is achieved because the physical features at the critical point are extended to nonzero temperature and for a small range of the control parameter around the critical point. In the out-of-equilibrium regime, we study the presence of a dynamical quantum critical region close to the critical time. In this context, to get an analogous picture with the equilibrium case, we have to substitute the control parameter with time, and temperature with the energy density.

TT 34.8 Tue 15:45 H22

Entanglement properties of continuous many-body systems via machine learning — •Fabio Hernandez-Hernandez[1,2] and Matthias Rupp[2] — [1]Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil — [2]Fritz Haber Institute of the Max Planck Society, Berlin, Germany

Quantum entanglement plays an important role in strongly correlated systems and new quantum technologies. However, computing entanglement properties of continuous systems such as atoms, molecules and materials is challenging. One of the most successful techniques for this, variational quantum Monte Carlo, requires a suitable parametrization of the wave function to identify a systems' ground state. The structure of this variational wave function determines which phenomena can be accessed. It should therefore be both general and efficiently computable. Building on recent work for discrete model systems, such as Ising and Hubbard models, [1] we propose to parametrize the ground state wave function of continuous systems via a Gaussian-Bernoulli Restricted Boltzmann Machine [2]. We demonstrate feasibility of this approach by calculating the linear entropy, a bipartite quantum entanglement measure, for two model systems, Hooke's atom and the helium atom. We discuss the utility of this approach to study critical phenomena and other exotic physical properties in strongly-correlated continuous systems.

[1] Carleo & Troyer, Science **355**, 602 (2017),
Nomura et al., Phys Rev B **96**, 205152 (2017)
[2] Melchior et al., PLoS One **12**, e0171015 (2017)