DY 46: Many-body Quantum Dynamics I

Time: Thursday 9:30–12:30 Location: HÜL 186

Invited Talk DY 46.1 Thu 9:30 HÜL 186

Nanofriction in Ion Coulomb Systems — •Tanja Mehlstäubler — QUEST-Institut an der PTB, Bundesallee 100, 38116 Braunschweig

Single trapped and laser-cooled ions in Paul traps allow for a high degree of control of atomic quantum systems. They are the basis for modern atomic clocks, quantum computers and quantum simulators. Our research aims to use ion Coulomb crystals, i.e. many-body systems with complex dynamics, for precision spectroscopy. This paves the way to novel optical frequency standards for applications such as relativistic geodesy and quantum simulators in which complex dynamics becomes accessible with atomic resolution.

The high-level of control of self-organized Coulomb crystals open up a fascinating insight into the non-equilibrium dynamics of coupled many-body systems, displaying atomic friction and symmetry-breaking phase transitions. We discuss the creation of topological defects and Kibble-Zurek tests in 2D crystals and present recent results on the study of tribology and transport mediated by the topological defect.

DY 46.2 Thu 10:00 HÜL 186

Charge-density-wave melting in the one-dimensional Holstein model — •Jan Stolpp[1], Jacek Herbrych[2], Florian Dorfner[3], Elbio Dagotto[4], and Fabian Heidrich-Meisner[1] — [1]Institut für Theoretische Physik, Universität Göttingen — [2]Wroclaw University of Science and Technology — [3]Arnold Sommerfeld Center for Theoretical Physics, Universität München — [4]Department of Physics and Astronomy, University of Tennessee and ORNL

In a recent preprint [1] we study the real-time dynamics in the half-filled Holstein model starting from different initial states that are charge-density-wave (CDW) ordered. The regime where the relaxation dynamics is dominated by electron-phonon coupling is considered (complementary to the case studied in [2] where strong electron interactions were present) and we focus on the far-from-equilibrium regime. Here, a clear separation of time scales between electron relaxation and phonon equilibration is identified. In the transient dynamics we observe effects like a temporal self trapping of the electrons. The study of such regimes is enabled by extending the time-evolving block decimation algorithm with local basis optimization, previously applied to single-polaron dynamics [3], to a half-filled system.

[1] Stolpp et al., arXiv:1911.01718 (2019)
[2] Hashimoto and Ishihara, PRB 96, 035154 (2017)
[3] Brockt et al., PRB 92, 241106(R) (2015)

DY 46.3 Thu 10:15 HÜL 186

Confinement Quench Dynamics on a Quantum Computer — •Joseph Vovrosh[1] and Johannes Knolle[1,2,3] — [1]Blackett Laboratory, Imperial College London, London, SW7 2AZ, United Kingdom — [2]Department of Physics, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

Confinement is a phenomenon that occurs when the attraction between two particles grows with their distance, most prominently found in quantum chromodynamics (QCD) between quarks. In condensed matter physics, similar phenomena occur in quantum spin chains, for example, in the one dimensional transverse field Ising model with an additional longitudinal field or as measured in scattering experiments on cobalt niobate. It turns out that confinement effects also lead to clear signatures in the non-equilibrium dynamics after a quantum quench. This makes confinement an ideal quantum effect to test the capabilities of quantum computers. Here, the underlying physics of confinement is explored in relation to quantum simulation on state of the art quantum computers. Quantum confinement is a non-perturbative interaction effect and its quantum simulation opens the possibilities to explore new quantum phenomena beyond the capabilities of classical computers.

DY 46.4 Thu 10:30 HÜL 186

Preparing Atomic Topological Quantum Matter by Adiabatic Non-Unitary Dynamics — Simone Barbarino[1], Jinlong Yu[2,3], Peter Zoller[2,3], and •Jan Carl Budich[1] — [1]Institute of Theoretical Physics, Technische Universität Dresden, 01062 Dresden, Germany — [2]Center for Quantum Physics, Faculty of Mathematics, Computer Science and Physics, University of Innsbruck, Innsbruck A-6020, Austria — [3]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Innsbruck A-6020, Austria

Motivated by the outstanding challenge of realizing low-temperature states of quantum matter in synthetic materials, we propose and study an experimentally feasible protocol for preparing topological states such as Chern insulators. By definition, such (non-symmetry protected) topological phases cannot be attained without going through a phase transition in a closed system, largely preventing their preparation in coherent dynamics. To overcome this fundamental caveat, we propose to couple the target system to a conjugate system, so as to prepare a symmetry protected topological phase in an extended system by intermittently breaking the protecting symmetry. Finally, the decoupled conjugate system is discarded, thus projecting onto the desired topological state in the target system. By construction, this protocol may be immediately generalized to the class of invertible topological phases, characterized by the existence of an inverse topological order. We illustrate our findings with microscopic simulations on an experimentally realistic Chern insulator model of ultracold fermionic atoms in a driven spin-dependent hexagonal optical lattice.

DY 46.5 Thu 10:45 HÜL 186

Hierarchy of double-time correlations for quenches in the Bose-Hubbard model — •Friedemann Queisser[1,2,3] and Ralf Schützhold[1,2,3] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, Duisburg 47057, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

The hierarchy of correlations is an analytical approximation method which allows us to study non-equilibrium phenomena in strongly interacting quantum many-body systems on lattices in higher dimensions (with the underlying idea being somewhat similar to dynamical mean-field theory). So far, this method was restricted to equal-time correlators such as $\langle \hat{A}_\mu(t)\hat{B}_\nu(t)\rangle$. Using the method of complete induction, we generalize this method to double-time correlators such as $\langle \hat{A}_\mu(t)\hat{B}_\nu(t')\rangle$, which allows us to study effective light cones and Green functions and to incorporate finite initial temperatures. As an application, we study the non-equilibrium dynamics after quantum quenches of the Bose-Hubbard model in the Mott insulator phase.

Reference: arXiv:1909.10938

15 min. break.

DY 46.6 Thu 11:15 HÜL 186

Boltzmann relaxation dynamics in the strongly interacting Fermi-Hubbard model — •Friedemann Queisser[1,2,3] and Ralf Schützhold[1,2,3] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, Duisburg 47057, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Via the hierarchy of correlations, we study the Mott insulator phase of the Fermi-Hubbard model in the limit of strong interactions and derive a quantum Boltzmann equation describing its relaxation dynamics. In stark contrast to the weakly interacting case, we find that the scattering cross sections strongly depend on the momenta of the colliding quasi-particles and holes. Therefore, the relaxation towards equilibrium crucially depends on the spectrum of excitations. For example, for particle-hole excitations directly at the minimum of the (direct) Mott gap, the scattering cross sections vanish such that these excitations can have a very long life-time.

Reference:

F. Queisser and R. Schützhold, Phys. Rev. A **100**, 053617 (2019)

DY 46.7 Thu 11:30 HÜL 186

Boltzmann relaxation dynamics of strongly interacting spinless fermions on a lattice — •Friedemann Queisser[1,2,3], Sebastian Schreiber[1], Peter Kratzer[1], and Ralf Schützhold[1,2,3] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, Duisburg 47057, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Motivated by the recent interest in nonequilibrium phenomena in quantum many-body systems, we study strongly interacting fermions on a lattice by deriving and numerically solving quantum Boltzmann equations that describe their relaxation to thermodynamic equilibrium. The derivation is carried out by inspecting the hierarchy of correlations within the framework of the 1/Z expansion. Applying the Markov approximation, we obtain the dynamic equations for the distribution functions. Interestingly, we find that in the strong-coupling limit, collisions between particles and holes dominate over particle-particle and hole-hole collisions – in stark contrast to weakly interacting systems. As a consequence, our numerical simulations show that the relaxation timescales strongly depend on the type of excitations (particles or holes or both) that are initially present.
Reference: arXiv:1909.12802

DY 46.8 Thu 11:45 HÜL 186

Enhancement of local pairing correlations in periodically driven Mott insulators — •Francesco Peronaci[1,2,3], Olivier Parcollet[1,4], and Marco Schiró[1] — [1]Institut de Physique Théorique (IPhT), CEA, CNRS, UMR 3681, 91191 Gif-sur-Yvette, France — [2]CPHT, Ecole Polytechnique, CNRS, Université Paris-Saclay, 91128 Palaiseau, France — [3]Max Planck Institute for the Physics of Complex Systems, Dresden 01187, Germany — [4]Center for Computational Quantum Physics, Flatiron Institute, 162 Fifth Avenue, New York, NY 10010, USA

We investigate a model for a Mott insulator in presence of a time-periodic modulated interaction and a coupling to a thermal reservoir. The combination of drive and dissipation leads to non-equilibrium steady states with a large number of doublon excitations, well above the maximum thermal-equilibrium value. We interpret this effect as an enhancement of local pairing correlations, providing analytical arguments based on a Floquet Hamiltonian. Remarkably, this Hamiltonian shows a tendency to develop long-range staggered superconducting correlations. This suggests the possibility of realizing the elusive eta-pairing phase in driven-dissipative Mott Insulators.

DY 46.9 Thu 12:00 HÜL 186

Hilbert space average of transition probabilities — •Nico Hahn and Daniel Waltner — Faculty of Physics, University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany

The typicality approach and the Hilbert space averaging method as its technical manifestation are important concepts of quantum statistical mechanics. Extensivley used for expectation values we will extend them to transition probabilities. We find that the transition probability of two random uniformly distributed states is connected to the spectral statistics of the considered operator. We will demonstrate our quite general result for a kicked spin chain.

DY 46.10 Thu 12:15 HÜL 186

Quenched Fermi systems mediating time delayed interactions — •Conor Jackson and Bernd Braunecker — University of St Andrews, St Andrews, UK

Impurity quenches in Fermi systems are known to substantially reorganise the Fermi sea, most dramatically illustrated by Anderson's orthogonality catastrophe. We investigate how the influence of the catastrophe is transmitted through the system, finding singular behaviour at the boundary of the light cone emanating from the quench. We examine how states localised some distance away from the impurity display the influence of the spreading shake up of the Fermi sea and explore using the long range effect of the quench to induce a time delayed interaction between such states. Such a coherent coupling via a largely incoherent medium may have uses in quantum information processing.