DY 29: Many-body Quantum Dynamics

Time: Wednesday 9:30–13:00 Location: H19

Invited Talk DY 29.1 Wed 9:30 H19

Dynamical localization in Z_2 lattice gauge theories — •Dmitry Kovrizhin — Rudolf Peierls Centre for Theoretical Physics

We study quantum quenches in two-dimensional lattice gauge theories with fermions coupled to Z_2 gauge fields. Through the identification of an extensive set of conserved quantities we propose a generic mechanism of dynamical localization in the absence of quenched disorder, and provide diagnostics of this localization via a set of measures including entanglement measures, and out-of-time-order correlators. We discuss applications of our general phenomenology of disorder-free localization to dynamics of defects in Kitaev's toric code, and quantum quenches in Hubbard models.

DY 29.2 Wed 10:00 H19

Localization Dynamics on a Quantum Computer — •Adam Smith, Florian Mintert, Peter Haynes, Myungshik Kim, and Johannes Knolle — Imperial College London, London UK

Universal quantum computers are potentially an ideal setting for simulating collective quantum dynamics that is out of reach for classical digital computers. We use a state-of-the-art IBM quantum computer to study one of the paradigmatic examples of condensed matter physics – we simulate the effects of disorder and interactions on quantum particle transport. Our benchmark results show that the quality of the current machines is below what is necessary for quantitatively accurate continuous time dynamics of observables and reachable system sizes are small comparable to exact diagonalization. On the plus side, we are successfully able to demonstrate clear qualitative localization behaviour that matches the expected many-body localization physics in a number of different settings. New optimization protocols combined with a roadmap for the study of localization phenomena on IBM machines hold a lot of promise for what can be simulated on near-term universal quantum computers.

DY 29.3 Wed 10:15 H19

Thermalization and emergent hydrodynamics in long range spin models — •Alexander Schuckert[1] and Michael Knap[1,2] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Institute for Advanced Study, Technical University of Munich, 85748 Garching, Germany

While local equilibration of nonequilibrium initial states in spin models has been extensively studied both theoretically and experimentally, comparatively less is known about the global thermalization due to the long time scales that emerge from transport of conserved charges.

We study emergent hydrodynamics in long range spin chains with the recently developed Schwinger boson spin-2PI method. A focus is put on the intricate interplay between long-range interaction exponent and hydrodynamic tail exponent, which in short range models is only connected to the dimensionality. As a measure of thermalization, the emergence of fluctuation-dissipation relations between spin-spin correlation functions is studied.

Finally, we discuss how our results can be implemented in existing trapped ion and Rydberg atom experiments.

DY 29.4 Wed 10:30 H19

Time Dependent Variational Monte Carlo in real and imaginary time — •Mathias Gartner[1,2] and Robert E. Zillich[2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria

The novel method of time dependent variational Monte Carlo simulations (t-VMC), by G. Carleo et al. [1], allows to simulate the time dynamics of quantum many-body systems. The method can also be used for imaginary time propagation which allows for optimizing parametrized ground state wavefunctions. It is shown that the imaginary time approach is suited to describe few-particle systems as well as bulk systems where up to 1000 particles in a periodic box are studied. The performed simulations demonstrate the possibility to efficiently optimize very generic trial wavefunctions, parametrized with up to a hundred parameters. For this purpose the well studied liquid ^{4}He serves as a test system for ground state optimization.

The current research focus lies on the simulation of real time dynamics of a bosonic model system with repulsive pair interaction undergoing a quench of the interaction strength. For this purpose a generic trial wavefunction that is felixible enough to descibe the dynamics of the strongly correlated system is developed. The results are compared to quench simulations employing the time dependent HNC-EL method.

[1] Scientific Reports **2**, 243 (2012)

DY 29.5 Wed 10:45 H19

Time evolution methods for matrix-product states — •Sebastian Paeckel[1], Thomas Köhler[1], Andreas Swoboda[2], Salvatore R. Manmana[1], Ulrich Schollwöck[2], and Claudius Hubig[3] — [1]Institut für Theoretische Physik, Universität Göttingen — [2]Departement of Physics and Arnold Sommerfeld Center for Theoretical Physics, LMU München — [3]Max-Planck-Institut für Quantenoptik Garching

Matrix-product states (MPS) have become the de facto standard for the investigation of one-dimensional quantum many body systems, also out-of-equilibrium. Various approaches have been introduced for computing the time evolution of MPS, e.g., a time-dependent variational principle (TDVP) for MPS as well as matrix product operator (MPOs) representations of the time evolution operator. In this talk I review important developments and compare five commonly used methods applied to representative examples, including systems with long-ranged interactions or in 2D. These results give insights to the state-of-the-art treatment of MPS out-of-equilibrium and a guideline for which method to choose for a problem at hand.

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DY 29.6 Wed 11:00 H19

Encoding quantum renormalization group transformations in artificial neural networks — Heiko Burau and •Markus Heyl — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Renormalization group methods are central tools for the description and understanding of equilibrium many-body systems. Far from equilibrium, however, they are facing challenges. Under the application of a renormalization group transformation typical initial conditions for quantum real-time dynamics can in many cases not be efficiently represented. In this work we show how such transformed initial states for systems of spin-1/2 degrees of freedom can be encoded generally in an artificial neural network. We apply this encoding for a strong-disorder renormalization group study of a disordered quantum Ising model and, in particular, its nonequilibrium real-time dynamics.

DY 29.7 Wed 11:15 H19

Observation of universal dynamics in a spinor Bose gas far from equilibrium — •Maximilian Prüfer[1], Philipp Kunkel[1], Helmut Strobel[1], Stefan Lannig[1], Daniel Linnemann[1], Christian-Marcel Schmied[1], Jürgen Berges[2], Thomas Gasenzer[1], and Markus K. Oberthaler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg — [2]Institut für Theoretische Physik, Universität Heidelberg

Far from equilibrium different scenarios on the way to equilibrium have been identified. Here, we present a new scenario featuring universal dynamics associated to the existence of non-thermal fixed points [1]. We access and study this regime experimentally for a Bose-Einstein condensate of ^{87}Rb in the F = 1 hyperfine manifold with ferromagnetic interactions. We quench an experimental control parameter, which leads to a build-up of excitations in the transversal spin. We identify a regime in the time evolution where the in-plane orientation of this spin becomes the relevant dynamical degree of freedom. Spatially resolved read-out allows the momentum resolved study of correlation functions which show rescaling in time and space - the dynamics is solely captured by a universal scaling function and associated exponents. We experimentally identify an emergent conserved quantity which is transported towards low momentum scales. By preparing different initial conditions we confirm that the non-thermal scaling involves no fine tuning of parameters.

[1] Prüfer, M. et al., Nature **563**, 217-220 (2018)

15 min break

DY 29.8 Wed 11:45 H19

Spin-models, dynamics and criticality with atoms in tilted optical superlattices — Anton Buyskikh[1], Luca Tagliacozzo[1], •Dirk Schuricht[2], Chris Hooley[3], David Pekker[4], and Andrew Daley[1] — [1]University of Strathclyde, Glasgow, UK — [2]Utrecht University, NL — [3]University of St Andrews, UK — [4]University of Pittsburgh, USA

We show that atoms in tilted optical superlattices provide a platform for exploring coupled spin chains of forms that are not present in other systems. In particular, using a period-2 superlattice in 1D, we show that coupled Ising spin chains with XZ and ZZ spin coupling terms can be engineered. We use optimized tensor network techniques to explore the criticality and non-equilibrium dynamics in these models, finding a tricritical Ising point in regimes that are accessible in current experiments. These setups are ideal for studying low-entropy physics, as initial entropy is *frozen-out* in realising the spin models.

DY 29.9 Wed 12:00 H19

Fingerprints of level repulsion in the work statistics of a mesoscopic grain — •Izabella Lovas[1,2] and Gergely Zarand[1] — [1]Budapest University of Technology and Economics, 1111 Budapest, Hungary — [2]Technische Universitat Munchen, D-85748 Garching, Germany

We investigate the out-of-equilibrium dynamics of non-interacting fermions in a generic mesocopic disordered grain, by combining numerical results with analytical considerations. We focus on the distribution of work, performed during quenches in different – orthogonal or unitary – random matrix ensembles, for a Fermi sea initial state. We analyze how this work statistics reflects the structure of particle-hole excitations, in particular, the level statistics of the underlying matrix ensemble.

We demonstrate that the initial Fermi sea shows a diffusive broadening during the quench, with the quench-velocity dependent diffusion coefficient reflecting the different level repulsion in the two ensembles. Turning to the full distribution of work, we find clear fingerprints of the rigidity of energy levels in the probability density function for slow quenches. Remarkably, the most important features of the work statistics can be captured by a classical Markovian description, taking into account only nearest neighbor level transitions of the fermions. Our results could be experimentally accessible by calorimetric measurements in mesoscopic settings.

DY 29.10 Wed 12:15 H19

Effective Hamiltonian theory of the geometric evolution of quantum systems — •Vlad Shkolnikov and Guido Burkard — Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We present an effective Hamiltonian description of the quantum dynamics of a generalized Lambda system undergoing adiabatic evolution [1]. We assume the system to be initialized in the dark subspace and show that its holonomic evolution can be viewed as a conventional Hamiltonian dynamics in an appropriately chosen extended Hilbert space. In contrast to the existing approaches, our method does not require the calculation of the non-Abelian Berry connection and can be applied without any parametrization of the dark subspace, which becomes a challenging problem with increasing system size.

[1] V.O. Shkolnikov and Guido Burkard, arXiv:1810.00193

DY 29.11 Wed 12:30 H19

Non-equilibrium Fluctuation theorems for strongly-coupled, non-thermal environments — •Javier Cerrillo — Institut für Theoretische Physik, Technische Universität Berlin, Hardenbergstr 36 10623 Berlin

We propose a novel form of symmetry for the derivation of fluctuation theorems that only requires the assumption of an initial local thermal state of the subsystem of interest. Therefore, they do not rely on the usual concepts of microscopic time-reversibility and global thermal state involving the environment. Moreover, these theorems apply regardless of the Markovianity of the subsystem or of the strength of its coupling to the environment. In the context of laser cooling of trapped ions, experimentally confirmed deviations from weak-coupling thermalization can be treated with this perspective. These deviations are often detrimental for the thermodynamic function as we have shown with help of Floquet-Markov-based simulation methods, due to the appearance of polaronic, correlated dynamics between the subsystem and its environment.

DY 29.12 Wed 12:45 H19

Ultrafast switch in graphene — •Hamed Koochaki Kelardeh[1], Alexandra Landsman[1,2], Vadym Apalkov[3], and Mark Stockman[3] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Max Planck Postech, Pohang, Republic of Korea — [3]Georgia State University, Atlanta, USA

We propose a switch made of graphene that acts on a one-fs scale and can controllably modulate the transient- induced photocurrent and carrier transport on the subcycle time scale (within one cycle of optical field). Few-cycle laser pulses generate a residual current, which is highly sensitive to the waveform of the driving laser. The residual current and charge transfer result from breaking the spatiotemporal symmetry of the system with few-cycle laser pulses. We investigate the carrier transport mechanism and criteria upon which we can manipulate its directionality and amplitude by the ellipticity, amplitude, and carrier-envelope phase of the pulse. For instance, we observe a change in current direction as a function of ellipticity when the polarization and the corresponding electron trajectories in the reciprocal space deform from linear to circular.