DY 2: Nonequilibrium Quantum Systems (joint session TT/DY)

Time: Monday 9:30–12:30 Location: H31

DY 2.1 Mon 9:30 H31

Solving the nonequilibrium Dyson equation with quantics tensor trains — •Ken Inayoshi[1], Maksymilian Środa[2], Anna Kauch[3], Philipp Werner[2], and Hiroshi Shinaoka[1] — [1]Department of Physics, Saitama University, Saitama, Japan — [2]Department of Physics, University of Fribourg, Fribourg, Switzerland — [3]Institute of Solid State Physics, TU Wien, Vienna, Austria

The nonequilibrium Green's function (NEGF) method is a powerful tool to investigate dynamical phenomena in quantum many-body systems. However, the time-translational symmetry breaking of Green's functions (GFs) makes the simulation of long-time dynamics computationally and memory-intensive. To overcome these, various memory compression techniques have been proposed for the NEGF method [1,2]. Among these, quantics tensor trains (QTT) have been attracting a focus for its ability to exponentially compress the data size of GFs [3]. While a prototype NEGF method with QTT has been developed [4], its benchmarks were limited to the short-time dynamics due to technical challenges such as the slow convergence of self-consistent calculations. We propose an improved implementation to reach the longer time regions, using a variational method for solving the Dyson equation and a causality-based divide-and-conquer algorithm [5,6]. In this contribution, we benchmark our method in relevant test cases [6].

[1] J. Kaye and D. Golež, SciPost Phys. **10**, 091 (2021).
[2] M. Eckstein, arXiv:2410.19707.
[3] H. Shinaoka *et al.*, Phys. Rev. X **13**, 021015 (2023).
[4] M. Murray *et al.*, Phys. Rev. B **109**, 165135 (2024).
[5] M. Środa *et al.*, in preparation
[6] K. Inayoshi *et al.*, in preparation

DY 2.2 Mon 9:45 H31

Fractionalized prethermalization in the one-dimensional Hubbard model — •Anton Romen[1,2], Johannes Knolle[1,2,3], and Michael Knap[1,2] — [1]Technical University of Munich, Garching, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Blackett Laboratory, Imperial College London, London, United Kingdom

Prethermalization phenomena in driven systems are generally understood via a local effective Floquet Hamiltonian. It turns out that this picture is insufficient for systems with fractionalized excitations. A first example is a driven Kitaev spin liquid which realizes a quasistationary state with vastly different temperatures of the matter and flux sectors, a phenomenon dubbed fractionalized prethermalization. In our work we argue that similar heating dynamics also occur in driven 1D tJ-models. In the weak doping limit of this model, the electron fractionalizes into quasiparticles carrying charge and spin. We show that the nonequilibrium heating dynamics of this model feature a quasistationary state characterized by a low spin and high charge temperature. We argue that the lifetime of this quasistationary state is determined by two competing processes depending on the specific drive chosen: A Fermi Golden Rule that describes the lifetime of the quasiparticles and the exponential lifetime of a Floquet prethermal plateau. Using a time dependent variant of the Schrieffer-Wolff transformation we systematically analyze the different classes of drives emerging from the respective Hubbard model. Lastly, we discuss potential ways towards an experimental realization in cold atom experiments.

DY 2.3 Mon 10:00 H31

Computing the lifetime of spin-orbital excitations in TiOCl using Lanczos techniques — •Paul Fadler[1,2], Philipp Hansmann[1], Kai Phillip Schmidt[1], Angela Montanaro[1,3], Filippo Glerean[4], Enrico Maria Rigoni[1,3], Daniele Fausti[1,3], and Martin Eckstein[2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg — [2]Universität Hamburg — [3]University of Trieste — [4]Harvard University, Cambridge

TiOCl is a spin-Peierls compound with optically active d-d-transitions at 0.7 eV and 1.5 eV. A pump-push-probe spectroscopy experiment on this system revealed a nonlinear signal asymmetric with respect to the order in which these transitions are pumped. This asymmetry could arise from differing lifetimes of the excitations due to multi-magnon and orbital-fission decay processes. To test this hypothesis we derive a spin-orbital Hamiltonian from ab-initio calculation. Within this description the pumped excitations are orbitons, i.e., hybrid spin-orbital quasiparticles, that can be understood as orbital excitations surrounded by a magnon cloud. We evaluate their lifetimes using Fermi's golden rule for all spin-orbital decay channels, which we compute on a large cluster using Lanczos techniques. Comparing the theoretical prediction to the asymmetry and absolute decay times of the nonlinear signal in the experiment we conclude, that multi-magnon and orbital-fission decay processes could be the dominant decay channels for the 0.7 eV excitation. On the other hand for the 1.5 eV excitation other types of processes such as phonon-assisted decays or nonlinearities in the double-pump scheme have to be taken into account.

DY 2.4 Mon 10:15 H31

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 physicist, but also for theoretical physicist 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 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 electron, the spin-spin correlation between localized spins, and the electronic momentum distribution momentum. The study includes a comparison with statistical mechanics predictions for steady state and a research of the effect of diagonal disorder.

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DY 2.5 Mon 10:30 H31

An attempt to extend the adiabatic theorem — •Sarah Damerow[1,2] and Stefan Kehrein[1] — [1]Institut für Theoretische Physik, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen — [2]I. Institut für Theoretische Physik, Universität Hamburg, Notkestraße 9-11, 22607 Hamburg

A conjectured extension of the adiabatic theorem to quantum quenches, i.e., maximally non-adiabatic changes, is presented.The proposed extension is framed as follows: "as long as quenched states within the same magnetic phase are concerned, the overlap between the initial and final ground states is the largest possible." This conjecture is investigated analytically and is tested numerically using Exact Diagonalisation in two models: the Transverse Field Ising Model (TFIM) and the Axial Next Nearest Neighbour Ising Model (ANNNI).

DY 2.6 Mon 10:45 H31

Towards Floquet-GW: interacting electrons in time-periodic potentials — •Ayan Pal[1,2], Erik G. C. P. van Loon[1,2], and Ferdi Aryasetiawan[1] — [1]Division of Mathematical Physics, Department of Physics, Lund University, Professorsgatan 1, 223 63, Lund, Sweden — [2]NanoLund, Lund University, Professorsgatan 1B, 223 63, Lund, Sweden

The Floquet theory of time-periodic systems provides a middle ground between equilibrium and completely non-equilibrium physics. Here, we study interacting electrons in time-periodic potentials using the combination of Floquet theory and many-body methods such as RPA and GW. We apply these techniques to the electron gas and to lattice models and study the electronic and dielectric properties, for example the appearance of side bands in the spectral functions. These methods have the potential to describe the impact of periodic laser pulses on the plasmonic and optical properties of (moderately) correlated materials.

15 min. break

DY 2.7 Mon 11:15 H31

Universal quench dynamics in Yukawa-Sachdev-Ye-Kitaev models — •Haixin Qiu and Stefan Kehrein — Institute for Theoretical Physics, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

Understanding the non-equilibrium properties of non-Fermi liquids without quasiparticles is essential for exploring the dynamics of strongly correlated systems. Here we investigate the quantum quench of a non-Fermi liquid model, the Yukawa-Sachdev-Ye-Kitaev model with interactions involving one boson and q fermions and its lattice extensions. We compute various in and out of equilibrium quantities for general q within the large-N dynamical mean field scheme by integrating the Kadanoff-Baym equations. We find transient oscillations and relaxation dynamics are insensitive to the quench amplitudes deep inside the non-Fermi liquid phase. Notably, the relaxation dynamics involve two distinct transient temperatures and relaxation rates for bosonic and fermionic degrees of freedom, both of which show non-Fermi liquid or universal behaviors. Signatures of prethermalization are also found when quenching near the Fermi liquid phase.

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DY 2.8 Mon 11:30 H31

Long-range induced synchronization of Higgs oscillations in topological superconductors — Andreas Alexander Buchheit[1], Benedikt Fauseweh[2,3], and •Torsten Kessler[4] — [1]Saarland University, Department of Mathematics and Computer Science, Germany — [2]TU Dortmund University, Department of Physics, Germany — [3]German Aerospace Center (DLR), Cologne, Germany — [4]Eindhoven University of Technology, Department of Mechanical Engineering, Netherlands

We investigate the impact of long-range electron-electron interactions on the non-equilibrium dynamics of unconventional superconductors. Using recently developed mathematical tools for the efficient treatment of longe-range interactions on lattices, we simulate the time evolution of a triplet superconductor with arbitrary power law interaction. Owing to the long-range interaction, a chiral phase with d+p symmetry emerges. We find that the long-range interaction stabilizes the Higgs oscillation in this phase. While the d-wave's initial mode decays rapidly, it begins to mirror the stable Higgs oscillation of the p-wave condensate part. Eventually, the two parts oscillate with a joint frequency. We demonstrate that this behavior can also be observed in the optical conductivity resulting from an external probe pulse.

DY 2.9 Mon 11:45 H31

Tuning of slow dynamics in quantum East Hamiltonians motivated by Graph theory — •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), Schelling Strasse 4, D-80799 München

In-between fully ergodic/localized quantum system there exist many systems with atypical relaxation behaviors. One of these systems is the quantum East (QE) model. The classical East model is a central, exemplary model for glassy dynamics and kinetic constraints. Also its quantum counterpart features slow dynamics without conservation laws or disorder. However, the presence of slow dynamics has not yet been fully understood from a quantum perspective. Introducing an interpretation of constrained dynamics based on graph theory, we theoretically demonstrate control over the slow dynamics of QE models. As a general hypothesis, we propose that strong hierarchies between nodes on the Fock space graph are related to the presence of slow dynamics. To quantify hierarchical structures, we develop a measure of centrality for generic Hamiltonian matrices, reminiscent of established centrality measures from graph theory. Based on these ideas, we show how we can introduce detuning to alter the hierarchical structure in the QE model and acutely change the resulting constrained dynamics, evidenced by eigenstate structure in the detuned QE models.

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DY 2.10 Mon 12:00 H31

Optical signatures of dynamical excitonic condensates — •Alexander Osterkorn[1], Yuta Murakami[2], Tatsuya Kaneko[3], Zhiyuan Sun[4], Andrew J. Millis[5,6], and Denis Golež[1,7] — [1]Jožef Stefan Institute, Ljubljana, Slovenia — [2]RIKEN, Wako, Japan — [3]Osaka University, Toyonaka, Japan — [4]Tsinghua University, Beijing, P.R. China — [5]Columbia University, New York, USA — [6]Flatiron Institute, New York, USA — [7]University of Ljubljana, Ljubljana, Slovenia

Excitons, or bound electron-hole pairs, can condense into an excitonic insulator state, similarly to Cooper pairs in superconductors. A non-equilibrium carrier concentration, such as the one transiently induced by photo-doping or sustained by a tuneable bias voltage in bilayers, can create a dynamical excitonic insulator state, yet proving phase coherence in such setups remains challenging. We examine the condensate phase behavior theoretically and show that optical spectroscopy can distinguish between phase-trapped and phase-delocalized dynamical regimes. In the weak-bias regime, trapped phase dynamics result in an in-gap absorption peak nearly independent of bias voltage, while at higher biases its frequency increases approximately linearly. In the large bias regime, the response current grows strongly under the application of a weak electric probe leading to negative weight in the optical response, which we analyze relative to predictions from a minimal model for the phase. This work opens new avenues for experimentally probing coherence in excitonic condensates and the detection of their dynamical regimes.

DY 2.11 Mon 12:15 H31

Visualizing dynamics of charges and strings in (2+1)D lattice gauge theories — Tyler A. Cochran[1,2], •Bernhard Jobst[3,4], Eliott Rosenberg[1], Yuri D. Lensky[1], Adam Gammon-Smith[5], Michael Knap[3,4], Frank Pollmann[3,4], and Pedram Roushan[1] — [1]Google Research, CA, USA — [2]Princeton University, NJ, USA — [3]Technical University of Munich, 85748 Garching, Germany — [4]MCQST, 80799 München, Germany — [5]University of Nottingham, NG7 2RD, UK

Lattice gauge theories (LGTs) can be employed to understand a wide range of phenomena. Studying their dynamical properties can be challenging as it requires solving many-body problems that are generally beyond perturbative limits. We investigate the dynamics of local excitations in a $\mathbb{Z}_2$ LGT using a two-dimensional lattice of superconducting qubits. We first construct a simple variational circuit which prepares low-energy states that have a large overlap with the ground state; then we create particles with local gates and simulate their quantum dynamics via a discretized time evolution. As the effective magnetic field is increased, our measurements show signatures of transitioning from deconfined to confined dynamics. For confined excitations, the magnetic field induces a tension in the string connecting them. Our method allows us to experimentally image string dynamics in a (2+1)D LGT from which we uncover two distinct regimes inside the confining phase: for weak confinement the string fluctuates strongly in the transverse direction, while for strong confinement transverse fluctuations are effectively frozen.