TT 53: Nonequilibrium Quantum Systems II (joint session TT/DY)

Time: Wednesday 15:00–17:30 Location: HSZ/0105

TT 53.1 Wed 15:00 HSZ/0105

Nonlocal Correlation Effects in the Relaxation Dynamics of the Photo-Excited Hubbard Model — •Gusein Bedirkhanov[1], Nagamalleswararao Dasari[2], Alexander I. Lichtenstein[2], and Evgeny A. Stepanov[1] — [1]CPHT, CNRS, École polytechnique, Institut Polytechnique de Paris, 91120 Palaiseau, France — [2]Institut für Theoretische Physik, Universität Hamburg, 22607 Hamburg, Germany

Experiments on ultrafast irradiation of correlated materials have revealed a variety of exotic nonequilibrium phenomena. A theoretical investigation of these phenomena requires methods capable of accurately describing a complex interplay between the non-perturbative local correlations and nonlocal collective electronic fluctuations throughout their relaxation pathway. A recently developed real-time nonequilibrium *D-GW* method allows for such a description by incorporating nonlocal charge and spin fluctuations diagrammatically, going beyond the dynamical mean-field theory solution. In this work, we apply *D-GW* to track the relaxation dynamics of a photo-excited Hubbard model across different interaction strengths, including the particularly challenging region near the Mott transition. To simulate the transfer of electronic energy to other degrees of freedom, we introduce controlled cooling by coupling the electronic system to various relaxation baths and compare their efficiency and physical implications. We analyze the emergent steady and metastable states, and investigate how interaction strength and nonlocal correlations shape the relaxation pathway.

TT 53.2 Wed 15:15 HSZ/0105

Optimizing energy conversion with nonthermal resources in steady-state quantum devices — •Elsa Danielsson, Henning Kirchberg, and Janine Splettstoesser — Chalmers University of Technology, Sweden

In quantum transport, particle currents are investigated through quantum devices coupled to multiple contacts, which are defined by their electrochemical potentials and temperatures. However, when reaching the nanoscale, particles might no longer equilibrate with their thermal surroundings. Consequently, in the investigation of energy conversion processes, nonthermal distributions become highly relevant descriptors of the particles' environment. I will present how a nonthermal resource can be exploited to generate power or cool a contact and how to maximize the efficiency or precision for these processes. Utilizing coherent electron scattering, the optimization is made by adjusting the transmission probabilities of electrons at different energies. Importantly, we also address the issue of how to define an efficiency as the energy current cannot be neatly divided into heat and work, due to the presence of a nonthermal resource. Based on this, we show that for a fixed output current the optimal transmission function is a series of band-passes in the energy spectrum, depending on the shape of the nonthermal distribution. When applying this result on example systems with nonthermal resources we find that all performance quantifiers improve compared to thermal counterparts. These findings highlight the importance of designing nanoelectronic devices according to the electron distributions their contacts.

TT 53.3 Wed 15:30 HSZ/0105

Excited State Phases of Matter in the SymTFT Paradigm — •Ludwig Zweng[1,2], Apoorv Tiwari[3], and Sanjay Moudgalya[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences — [2]Munich Center for Quantum Science and Technology (MCQST) — [3]Southern Denmark University, Center for Quantum Mathematics at IMADA

Recent works have developed a unifying framework for classifying ground state phases of matter with a wide range of discrete symmetries—both group-like and non-invertible symmetries—via a holographic correspondence between symmetric operators in d dimensions and topological operators in a d+1 dimensional system often known as the SymTO or SymTFT. Its lattice formulation naturally yields fixed-point commuting Hamiltonians that realize these phases in their ground state. In this work, we extend this framework to non-equilibrium settings by analyzing excited states of these fixed-point models. Characterizing symmetry breaking patterns in the excited states requires new tools and diagnostic methods, which we develop to find that they can differ dramatically from their ground state counterparts, leading to a rich and sometimes surprising phenomenology. We illustrate these phenomena by constructing lattice models for a variety of invertible and non-invertible symmetries, classifying the distinct excited state phases that arise in each case. Finally, we propose a concrete definition of excited state phases of matter and argue that the SymTFTs that capture ground state phases do not fully capture the intricacies of the excited states.

TT 53.4 Wed 15:45 HSZ/0105

Improving the stability of the hierarchical equations of motion approach for generic bosonic spectral densities — •Salvatore Gatto, Samuel Rudge, and Michael Thoss — University of Freiburg

The hierarchical equations of motion (HEOM) constitute a numerically exact method for investigating the dynamics of open quantum systems across a wide range of environmental conditions [1]. In this contribution, we investigate the stability of HEOM for generic bosonic spectral densities and identify temperature- and coupling-dependent instabilities in the time evolution. We show that, upon increasing the system-bath coupling strength, the conventional HEOM formulation may become unstable, and that simply extending the hierarchy depth does not cure these long-time divergences [2]. Starting from the HEOM structure, we derive a multidimensional phase-space differential equation that generalizes the Quantum Fokker-Planck equation to arbitrary temperature [3]. We further demonstrate that expanding this new equation in an alternative basis removes the numerical instabilities inherent to the standard HEOM representation.

[1] J. Bätge, Y. Ke, C. Kaspar, M. Thoss, PRB 103, 235413 (2021)
[2] I. S. Dunn, R. Tempelaar, D. R. Reichman, J. Chem. Phys. 150, 184109 (2019)
[3] T. Li, Y. Yan, and Q. Shi, J. Chem. Phys. 156, 064107 (2022)

TT 53.5 Wed 16:00 HSZ/0105

Non-Local Correlation effects in DC and optical conductivity of the Hubbard model — Nagamalleswararao Dasari[1], Hugo Strand[2], Martin Eckstein[1], Alexander Lichtenstein[1], and •Evgeny Stepanov[3] — [1]Universität Hamburg, Germany — [2]Örebro University, Sweden — [3]CPHT, CNRS, École polytechnique, France

Many-body effects in correlated materials can be explored through various response functions, with transport measurements being among the simplest and most direct probes. Accurately addressing the unconventional transport properties of materials requires accounting for spatial electronic correlations. These correlations can significantly influence transport characteristics by modifying the electronic spectral function and giving rise to complex multi-electron scattering processes, known as vertex corrections, which can both strongly impact the conductivity. In this talk, I will discuss the impact of non-local correlations on the conductivity of the single-band Hubbard model within the recently developed D-GW method [arXiv:2507.16673]. I will demonstrate that the impact of non-local correlations on the conductivity differs between the correlated metallic and Mott insulating phases. Incorporating non-local correlations in both the electronic spectral function and vertex corrections is crucial for accurately describing the optical conductivity at finite frequencies in both these regimes. The crossover between the metallic and Mott insulating phases can be identified by a vanishing contribution of vertex corrections to the DC conductivity.

15 min. break

TT 53.6 Wed 16:30 HSZ/0105

Conditioning Subsystem Magnetization into the Large-Deviation Regime in Quantum Spin Chains — •Kriti Baweja[1], Samuel Garratt[2], David Luitz[1], Ali Zahra[3,4], and Jérôme Dubail[3,5] — [1]Institute of Physics, University of Bonn, Germany — [2]Department of Physics, Princeton University, USA — [3]Laboratoire de Physique et Chimie Théoriques, University of Lorraine, France — [4]Centro de Análise Matemática, Departamento de Matemática, Universidade de Lisboa, Portugal — [5]Centre Européen de Sciences Quantiques and ISIS, University of Strasbourg, France

We investigate the ground-state and finite-temperature properties of free-fermion and XXZ spin systems when a contiguous spatial region of the chain is conditioned to have a fixed value of its total S^z. We analyze

how this conditioning operation reshapes the local magnetization profile and longitudinal spin-spin correlations both within the constrained region and in its surrounding environment. To access regimes beyond analytically tractable limits, we extend an existing post-measurement Quantum Monte Carlo (QMC) framework by introducing new update rules that enable efficient sampling of states with arbitrary subsystem magnetization. Using this post-measurement QMC approach, we probe the finite-temperature properties of these conditioned states and characterize how magnetization constraints modify local structure in both interacting and non-interacting spin models. Our results provide a computational tool for exploring measurement-induced constraints and conditioned ensembles in quantum many-body systems.

TT 53.7 Wed 16:45 HSZ/0105

Consistent quantum treatments of nonconvex kinetic energies — Christina Koliofoti, Mohammad Atif Javed, and •Roman-Pascal Riwar — Peter Grünberg Institut (PGI-2), Forschungszentrum Jülich, 52428 Jülich, Germany

The task of finding a consistent relationship between a quantum Hamiltonian and a classical Lagrangian is of utmost importance for basic, but ubiquitous techniques like canonical quantization and path integrals. Nonconvex kinetic energies (which appear, e.g., in nonlinear capacitors or classical time crystals) pose a fundamental problem: the Legendre transformation is ill-defined, and the more general Legendre-Fenchel transformation removes nonconvexity essentially by definition. Arguing that such anomalous theories follow from suitable low-energy approximations of well-defined, harmonic theories, we show that seemingly inconsistent Hamiltonian and Lagrangian descriptions can both be valid, depending on the coupling strength to a dissipative environment. There occurs a dissipative phase transition from a nonconvex Hamiltonian to a convex Lagrangian regime, involving exceptional points in imaginary time. Our approach thus resolves apparent inconsistencies and provides computationally effcient methods to treat anomalous, nonconvex kinetic energies.

TT 53.8 Wed 17:00 HSZ/0105

Lanczos-Pascal approach to correlation functions in chaotic quantum systems — •Merlin Füllgraf, Jiaozi Wang, Robin Steinigeweg, and Jochen Gemmer — University of Osnabrück, Departement of Mathematics/Computer Science/Physics, D-49076 Osnabrück, Germany

We suggest a method to compute approximations to temporal correlation functions of few-body observables in chaotic many-body systems in the thermodynamic limit based on the respective Lanczos coefficients. Given the knowledge of these Lanczos coefficients, the method is very cheap. Usually accuracy increases with more Lanczos coefficients taken into account, however, we numerically find and analytically argue that the convergence is rather quick, if the Lanczos coefficients exhibit a smoothly increasing structure. For pertinent examples we compare with data from dynamical typicality computations for large but finite systems and find good agreement if few Lanczos coefficients are taken into account. From the method it is evident that in these cases the correlation functions are well described by a low number of damped oscillations.
[1] Accepted in Phys. Rev. Lett.

TT 53.9 Wed 17:15 HSZ/0105

Many-body neural network wavefunction for a non-Hermitian Ising chain — •Lavoisier Wah — Max Planck Institute for the Science of Light, 91058 Erlangen, Germany

Non-Hermitian (NH) quantum systems have emerged as a powerful framework for describing open quantum systems, non-equilibrium dynamics, and engineered quantum optical materials. However, solving the ground-state properties of NH systems is challenging due to the exponential scaling of the Hilbert space, and exotic phenomena such as the emergence of exceptional points. Another challenge arises from the limitations of traditional methods like exact diagonalization (ED). For the past decade, neural networks (NN) have shown promise in approximating many-body wavefunctions, yet their application to NH systems remains largely unexplored. In this paper, we explore different NN architectures to investigate the ground-state properties of a parity-time-symmetric, one-dimensional NH, transverse field Ising model with a complex spectrum by employing a recurrent neural network (RNN), a restricted Boltzmann machine (RBM), and a multilayer perceptron (MLP). We construct the NN-based many-body wavefunctions and validate our approach by recovering the ground-state properties of the model for small system sizes, finding excellent agreement with ED. Then, for larger system sizes, we demonstrate that the RNN outperforms both the RBM and MLP. These results highlight the potential of neural network-based approaches - particularly for accurately capturing the low-energy physics of NH quantum systems both in case of weak and strong non-Hermiticity.