DY 25: Many-Body Quantum Dynamics (joint session DY/TT)

Time: Wednesday 9:30–13:00 Location: MOL 213

Invited Talk DY 25.1 Wed 9:30 MOL 213

Many-body localization from Hilbert- and real-space points of view — •Ivan Khaymovich[1], Giuseppe De Tomasi[2], Frank Pollmann[3], and Simone Warzel[3] — [1]Nordic Institute for Theoretical Physics, Stockholm, Sweden — [2]University of Illinois Urbana-Champaign, USA — [3]Technical University Munich, Germany

Many-body localization (MBL), known as a generic mechanism to break quantum ergodicity, has been recently shown to be not the Hilbert-space Anderson localization. Instead, the MBL eigenstate occupies a fractal support [1-2], with extensive number of configurations. On the other hand, the well-established and accepted by the community picture of an emergent set of local integrals of motion [3] provides the structure of the MBL in the real space.

In this talk, I will provide the observable (later measured in the experiment [4]) which combines the fractality in the Hilbert space with the presence of local integrals of motion [2]. This observable, being the radial profile of the eigenstate over the Hamming distance, keeps the information about both the Hilbert-space fractal dimensions and the real-space localization lengths and uncovers the structure of these measures across the MBL transition. Phenomenological picture behind this behavior is consistent with the Kosterlitz-Thouless scenario of the MBL transition, suggested in the literature.

Literature: [1] N. Macé et al., PRL 123, 180601 (2019). [2] G. De Tomasi, I. M. Khaymovich et al. PRB 104, 024202 (2021). [3] Abanin et al., RMP 91, 021001 (2019). [4] Y. Yao et al arXiv:2211.05803.

DY 25.2 Wed 10:00 MOL 213

Bridging classical and quantum many-body information dynamics — •Andrea Pizzi[1,2], Daniel Malz[3,4], Andreas Nunnenkamp[5], and Johannes Knolle[6,4,7] — [1]Department of Physics, Harvard University, Cambridge 02138, Massachusetts, USA — [2]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom — [3]Max-Planck-Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany — [5]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1190 Vienna, Austria — [6]Department of Physics, Technische Universität München, James-Franck-Stra. 1, 85748 Garching, Germany — [7]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

The fundamental question of how information spreads in closed quantum many-body systems is often addressed through the lens of the bipartite entanglement entropy. Among its most striking features are unbounded linear growth in the thermodynamic limit, asymptotic extensivity in finite-size systems, and measurement-induced phase transitions. Here, we show that these key qualitative features emerge naturally also for the classical bipartite mutual information, the natural classical analogue of the quantum entanglement entropy. Key for this observation is treating the classical many-body problem on par with the quantum one, that is, explicitly accounting for the exponentially large probability distribution. Our analysis is supported by extensive numerics on prototypical cellular automata and Hamiltonian systems.

DY 25.3 Wed 10:15 MOL 213

Performance boost of a collective qutrit refrigerator — •Dmytro Kolisnyk[1] and Gernot Schaller[2] — [1]Jacobs University Bremen, Campus Ring 1, 28759 Bremen, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany

A single qutrit with transitions selectively driven by weakly-coupled reservoirs can implement one of the world's smallest refrigerators. We analyze the performance of N such fridges that are collectively coupled to the reservoirs. We observe a quantum boost, manifest in a quadratic scaling of the steady-state cooling current with N. As N grows further, the scaling reduces to linear, since the transitions responsible for the quantum boost become energetically unfavorable. Fine-tuned inter-qutrit interactions may be used to maintain the quantum boost for all N and also for not-perfectly collective scenarios.

[1] D. Kolisnyk and G. Schaller, Performance boost of a collective qutrit refrigerator, arXiv:2210.07844.

[2] M. Kloc, K. Meier, K. Hadjikyriakos, and G. Schaller, Superradiant Many-Qubit Absorption Refrigerator, Phys. Rev. Applied 16, 044061 (2021).

[3] N. Linden, S. Popescu, and P. Skrzypczyk. How small can thermal machines be? The smallest possible refrigerator. Phys. Rev. Lett. 105:130401, 2010.

DY 25.4 Wed 10:30 MOL 213

Hidden Phase of the Spin-Boson Model — •Florian Otterpohl[1,2], Peter Nalbach[3], and Michael Thorwart[2,4] — [1]Center for Computational Quantum Physics, Flatiron Institute, New York, New York 10010, USA — [2]I. Institut für Theoretische Physik, Universität Hamburg, Notkestraße 9, 22607 Hamburg, Germany — [3]Fachbereich Wirtschaft und Informationstechnik, Westfälische Hochschule, Münsterstraße 265 46397 Bocholt, Germany — [4]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

A quantum two-level system immersed in a sub-Ohmic bath experiences enhanced low-frequency quantum statistical fluctuations which render the nonequilibrium quantum dynamics highly non-Markovian. Upon using the numerically exact time-evolving matrix product operator approach, we investigate the phase diagram of the polarization dynamics. In addition to the known phases of damped coherent oscillatory dynamics and overdamped decay, we identify a new third region in the phase diagram for strong coupling showing an aperiodic behavior. We determine the corresponding phase boundaries. The dynamics of the quantum two-state system herein is not coherent by itself but slaved to the oscillatory bath dynamics.

DY 25.5 Wed 10:45 MOL 213

Exploring anomalies by many-body correlations — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN, Campus Universitário Lagoa nova,59078-970 Natal, Brazil

The quantum anomaly can be written alternatively into a form violating conservation laws or as non-gauge invariant currents seen explicitly on the example of chiral anomaly. By reinterpreting the many-body averaging, the connection to Pauli-Villars regularization is established which gives the anomalous term a new interpretation as arising from quantum fluctuations by many-body correlations at short distances. This is exemplified by using an effective many-body quantum potential which realizes quantum Slater sums by classical calculations. It is shown that these quantum potentials avoid the quantum anomaly but approaches the same anomalous result by many-body correlations. A measure for the quality of quantum potentials is suggested to describe these quantum fluctuations in the mean energy. Consequently quantum anomalies might be a short-cut way of single-particle field theory to account for many-body effects. This conjecture is also supported since the chiral anomaly can be derived by a completely conserving quantum kinetic theory. [Eur. Phys. J. B 92 (2019) 176, Phys. Lett. A 383 (2019) 1362, Phys. Status Solidi B (2021) 2100316]

DY 25.6 Wed 11:00 MOL 213

Non-Markovian Stochastic Schrödinger Equation: Matrix Product State Approach to the Hierarchy of Pure States — Xing Gao[1], Jiajun Ren[2], Zhigang Shuai[2], and •Alexander Eisfeld[3] — [1]Sun Yat-sen University, Shenzhen, Guangdong, China — [2]Tsinghua University, Beijing, China — [3]MPI-PKS, Dresden

We derive a stochastic hierarchy of matrix product states (HOMPS) for non-Markovian dynamics in open quantum system at finite temperature, which is numerically exact and efficient. HOMPS is obtained from the stochastic hierarchy of pure states (HOPS) by expressing HOPS in terms of formal creation and annihilation operators. The resulting stochastic first order differential equation is then formulated in terms of matrix product states and matrix product operators. In this way the exponential complexity of HOPS can be reduced to scale polynomial with the number of particles. The validity and efficiency of HOMPS is demonstrated for the spin-boson model and long chains where each site is coupled to a structured, strongly non-Markovian environment.

[1] X. Gao, J. Ren, A. Eisfeld, Z. Shuai, *Phys. Rev. A* 105, L030202 (2022)

DY 25.7 Wed 11:15 MOL 213

ultrafast gap dynamics near the zone boundary in a cuprate superconductor — •qinda guo, maciej dendzik, magnus berntsen, cong li, wanyu chen, yang wang, dibya phuyal, and oscar tjernberg — Department of Applied Physics, KTH Royal Institute of Technology, Hannes Alfvéns väg 12, 114 19 Stockholm, Sweden

The time- and angle- resolved photoemission spectroscopy (tr-ARPES) is a powerful technique to directly probe the ultrafast electron dynamics in the momentum space. Our recently developed narrow-bandwidth tr-ARPES setup enabled us to access the ultrafast dynamics of the quasiparticle population as well as the superconducting gap, in the whole surface Brillouin zone of the photoexcited cuprate superconductor (Bi2212). The results show non-trivial dynamics at the d-wave antinode and provide new insights into the enigma of the Cooper-pair formation process and condensation that takes place in the high-temperature cuprate superconductor.

15 min. break

DY 25.8 Wed 11:45 MOL 213

Controlling Many-Body Quantum Chaos — •Lukas Beringer[1], Steven Tomsovic[1,2], Juan Diego Urbina[1], and Klaus Richter[1] — [1]Institut für Theoretische Physik, Universität Regensburg, D-93040 Regensburg, Germany — [2]Department of Physics and Astronomy, Washington State University, Pullman, WA USA

Targeting in classical chaos control problems makes optimal use of the system's exponential instabilities to direct a given initial state to a predetermined final target state. A generalization to chaotic quantum systems in the semiclassical regime is possible [1], but also requires controlling an initially localized evolving quantum state's spreading. A coherent procedure of this kind enables directing highly excited, far-out-of-equilibrium states from an initial to some final target quantum state. Such methods have been successfully developed and applied to initially minimum uncertainty wave packets in a quantum kicked rotor system. The aim of our work is to extend those procedures to bosonic many-body systems. More specifically, we demonstrate how to make a localized quantum initial state follow special chaotic mean-field solutions of a Bose-Hubbard system toward an arbitrary localized target final state.

[1] S. Tomsovic, J. D. Urbina, and Klaus Richter, Controlling Quantum Chaos: Optimal Coherent Targeting, arXiv:2211.07408

DY 25.9 Wed 12:00 MOL 213

Environment-induced decay dynamics of antiferromagnetic order in Mott-Hubbard systems — •Gernot Schaller[1], Friedemann Queisser[1,2], Nikodem Szpak[3], Jürgen König[3], and Ralf Schützhold[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [3]Fakultät für Physik and CENIDE, Universität Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany

We study the dissipative Fermi-Hubbard model in the limit of weak tunneling and strong repulsive interactions, where each lattice site is tunnel-coupled to a Markovian fermionic bath. For cold baths at intermediate chemical potentials, the Mott insulator property remains stable and we find a fast relaxation of the particle number towards half filling. On longer time scales, we find that the antiferromagnetic order of the Mott-Néel ground state on bipartite lattices decays, even at zero temperature. For zero and nonzero temperatures, we quantify the different relaxation time scales by means of waiting time distributions, which can be derived from an effective (non-Hermitian) Hamiltonian and obtain fully analytic expressions for the Fermi-Hubbard model on a tetramer ring.

[1] G. Schaller *et al.*, Phys. Rev. B **105**, 115139 (2022).

DY 25.10 Wed 12:15 MOL 213

Arrow of time concept based on properties of Lanczos coefficients — •Christian Bartsch, Mats H. Lamann, Robin Heveling, Lars Knipschild, Jiaozi Wang, Robin Steinigeweg, and Jochen Gemmer — Fachbereich Physik, Universität Osnabrück, Barbarastraße 7, DE-49076 Osnabrück

We introduce an arrow of time concept based on a specifically defined class of arrow of time functions (ATF) consisting of a limited number of Krylov space generating observables. These ATF'S are found to be essentially monotonously decaying in time which is measured by some quantifying parameter. The ATF's are constructed to be upper bounds for pertinent autocorrelation functions. Employing certain features of the Lanczos coefficients and the wave package-like excitation moving on the Krylov chain, we find reasonable agreement with corresponding numerics.

DY 25.11 Wed 12:30 MOL 213

Fast Time-Evolution of Matrix-Product States using the QR decomposition — •Jakob Unfried[1,2], Johannes Hauschild[1], and Frank Pollmann[1,2] — [1]Department of Physics, TFK, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MC-QST), Schellingstr. 4, 80799 München, Germany

Numerical simulations of quantum many-body dynamics in and out of equilibrium is essential for the understanding of a wide range of physical phenomena. Efficient matrix product state simulation techniques, such as time evolution block decimation (TEBD), are widely successful in extracting experimentally relevant signatures, such as dynamical correlation functions. We propose and benchmark a modified TEBD algorithm that uses a truncation scheme based on the QR decomposition instead of the singular value decomposition (SVD). The modification reduces the scaling with the dimension of the physical Hilbert space d from d^3 down to d^2. Unlike the SVD, the QR decomposition allows for highly efficient implementations on GPU hardware. In a benchmark simulation of a global quench in a quantum clock model, we observe a speedup of orders of magnitude comparing the QR based scheme on a GPU to the SVD based TEBD on CPU.

DY 25.12 Wed 12:45 MOL 213

Simulating infinite temperature spin dynamics by a dynamic mean-field theory — •Timo Gräßer[1], Kristine Rezai[2], Alexander O. Sushkov[2], and Götz S. Uhrig[1] — [1]Condensed Matter Theory, TU Dortmund University, Otto-Hahn Straße 4, 44221 Dortmund, Germany — [2]Department of Physics, Boston University, Boston, MA 02215, USA

We develop a dynamic mean-field theory for spin systems at infinite temperature (spinDMFT) [1]. The idea is to replace the large environment of a spin by a dynamic mean-field which displays a random Gaussian temporal evolution. Its autocorrelations are self-consistently linked to the quantum mechanic expectation values of spin-spin correlations. This approach becomes exact in the limit of large lattice coordination numbers. We improve the approach by considering spin clusters quantum-mechanically (cluster spinDMFT). The extended model is able to describe dynamic spin correlations measured in recent experiments [2] where an inhomogeneous spin-$\frac{1}{2}$ ensemble on a diamond surface is probed using nitrogen-vacancy centers as sensors.

[1] T. Gräßer et al., Phys. Rev. Research **3**, 043168 (2021).

[2] K. Rezai et al., arXiv:2207.10688 (2022).