TT 19: Many-body Quantum Dynamics I (joint session DY/TT)

Time: Tuesday 9:30–13:00 Location: H37

TT 19.1 Tue 9:30 H37

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

Controlling chaos is a well-established technique that leverages the exponential sensitivity of classical chaotic systems for efficient control. This concept has been generalized to single-particle quantum systems [1] and, more recently, extended to bosonic many-body quantum systems described by the Bose-Hubbard model [2]. In direct analogy to the classical paradigm, a localized quantum state can be transported along a specific trajectory to a desired target state. In the latter context, this approach reduces to time-dependent control of the chemical potentials, making it suitable for implementation in optical lattice experiments. Highlighted potential applications are rapid, customizable state preparation and stabilization of quantum many-body scars in one-, two-, and three-dimensional lattices. Recent progress includes potential applications to large time-crystal platforms and preparation protocols for entangled states, such as cat-like states.

[1] S. Tomsovic, J. D. Urbina, and Klaus Richter, Controlling Quantum Chaos: Optimal Coherent Targeting, PRL 130.2 (2023): 020201.

[2] L. Beringer, M. Steinhuber, J. D. Urbina, K. Richter, S. Tomsovic, Controlling many-body quantum chaos: Bose-Hubbard systems, New J. Phys (2024): 26 073002.

TT 19.2 Tue 9:45 H37

Exact spectral function and nonequilibrium dynamics of the strongly interacting Hubbard model — Ovidiu I. Pâţu[1], •Andreas Klümper[2], and Angela Foerster[3] — [1]Institute for Space Sciences, Bucharest-Măgurele, R 077125, Romania — [2]Fakultät für Mathematik und Naturwissenschaften, Bergische Universität Wuppertal, 42097 Wuppertal, Germany — [3]Instituto de Física da UFRGS, Av. Bento Gonçalves 9500, Porto Alegre, RS, Brazil

Analytical results on the correlation functions of strongly correlated many-body systems are rare in the literature and their importance cannot be overstated. We present determinant representations for the space-, time-, and temperature-dependent correlation functions of the strongly interacting one-dimensional Hubbard model in the presence of an external trapping potential. These representations are exact and valid in both equilibrium and nonequilibrium scenarios like the ones initiated by a sudden change of the confinement potential. In addition, they can be implemented numerically very easily significantly outperforming other numerical approaches. As applications of our results we investigate the single particle spectral functions of systems with harmonic trapping and show that dynamical quasicondensation occurs for both fermionic and bosonic spin-1/2 systems released from a Mott insulator state.

TT 19.3 Tue 10:00 H37

Quantum many-body scars beyond the PXP model in Rydberg simulators — Aron Kerschbaumer[1], Marko Ljubotina[1,2,3], Maksym Serbyn[1], and •Jean-Yves Desaules[1] — [1]Institute of Science and Technology Austria, Klosterneuburg, Austria — [2]Technical University of Munich, Garching, Germany — [3]Munich Center for Quantum Science and Technology, Munich, Germany

Persistent revivals recently observed in Rydberg atom simulators have challenged our understanding of thermalization and attracted much interest to the concept of quantum many-body scars (QMBSs). QMBSs are non-thermal highly excited eigenstates that coexist with typical eigenstates in the spectrum of many-body Hamiltonians, and have since been reported in multiple theoretical models, including the so-called PXP model, approximately realized by Rydberg simulators. At the same time, questions of how common QMBSs are and in what models they are physically realized remain open.

In our work, we demonstrate that QMBSs exist in a broader family of models that includes and generalizes PXP to longer-range constraints and states with different periodicity. We show that in each model, multiple QMBS families can be found. Each of them relies on a different approximate su(2) algebra, leading to oscillatory dynamics in all cases. However, in contrast to the PXP model, their observation requires launching dynamics from weakly entangled initial states rather than from a product state. The new QMBSs we unveil may be experimentally probed using Rydberg atom simulator in the regime of longer-range Rydberg blockades.

TT 19.4 Tue 10:15 H37

Roughening dynamics of quantum interfaces — Wladislaw Krinitsin[1,2], •Niklas Tausendpfund[1,3], Matteo Rizzi[1,3], Markus Heyl[4], and Markus Schmitt[1,2] — [1]Institute of Quantum Control (PGI-8), Forschungszentrum Jülich, Jülich, Germany — [2]Faculty of Informatics and Data Science, University of Regensburg, Regensburg, Germany — [3]Institute for Theoretical Physics, University of Cologne, Köln, Germany — [4]Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

The roughening transition, known from three-dimensional classical spin systems, describes how fluctuations of interfaces transition from being bounded to being extensive when crossing the characteristic roughening temperature. We explore signatures of such phenomena in the dynamics of domain walls in the two dimensional quantum Ising model, where we observe pre-thermal steady states in their evolution well beyond the perturbative limit using Tree Tensor Networks. We formulate an effective model of the interface, which captures qualitative features of a roughening transition. Most notably, it exhibits a Berezinskii Kosterlitz Thouless quantum phase transition from smooth to rough interfaces, whose signatures extend to finite temperatures. These findings can be related to the observed slow thermalization in the full model, opening the way to a better understanding of prethermalization effects in interface dynamics, which can be easily implemented and tested in experimental setups such as Rydberg atom experiments.

TT 19.5 Tue 10:30 H37

Semigroup Influence Functionals for the Dynamics of Quantum Impurity Models — •Michael Sonner[1], Valentin Link[2], and Dmitry Abanin[3,4] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, D-01187 Dresden, Germany — [2]Institut für Theoretische Physik, Technische Universität Dresden, D-01062 Dresden, Germany — [3]Department of Physics, Princeton University, Princeton, New Jersey 08544, USA — [4]Google Research, Brandschenkestrasse 150, 8002 Zürich, Switzerland

Quantum impurity models~(QIM) consist of a local interacting impurity which is coupled to baths of free fermions. These models exhibit a range of non-trivial phenomena such as the Kondo effect. and play a central role in the dynamic mean field theory (DMFT) approach to correlated matter. However, despite their importance, computing the real time dynamics of QIM remains a challenge. Recently, approaches based on matrix product states (MPS) representation of influence functionals (IF) have been proven effective approaches to this problem. These method work by capturing the, generically non-markovian dynamical effects of the quantum environments on the local impurity in a multi time object, which then is compressed as MPS. Taking explicit advantage of time-translation invariance of the model, we find an infinite MPS or semigroup representation of the IF. I will demonstrate how these ideas can be used to predict QIM dynamics for very long times as well as give direct access to stationary non-equilibrium states.

TT 19.6 Tue 10:45 H37

Quantum Fisher information of monitored random circuits — •Arnau Lira Solanilla, Xhek Turkeshi, and Silvia Pappalardi — Universität zu Köln

We characterize the multipartite entanglement structure of monitored random quantum circuits using the quantum Fisher information. We show that, despite the known phase transition in bipartite correlations, the multipartiteness is bounded. On the other hand, we generate a phase with extensive multipartite entanglement under symmetry preserving random operations by introducing two-qubit measurements. We focus on the limit where no unitary operations are applied, but there is a competition between two noncommuting projective measurements. We exploit a map to bond percolation to precisely calculate the universal scaling of multipartite entanglement.

TT 19.7 Tue 11:00 H37

Entanglement in quantum circuits with SU(2) symmetry — •Tobias Dörstel and Michael Buchhold — Institute for Theoretical Physics, Cologne

Quantum circuits offer a robust framework for studying the out-of-equilibrium dynamics of quantum many-body systems. We investigate one-dimensional monitored quantum circuits with global SU(2) symmetry, serving as digital counterparts to the Heisenberg chain. These circuits consist of unitary qubit SWAPs and non-unitary SWAP-measurements. Entanglement in the chain is governed by the configuration of qubit singlet states, whose count is fixed by the symmetry sector. Varying the measurement rate, unitary operations, and singlet number reveals diverse entanglement behaviors, ranging from volume law to $\log^2(L)$ and $\log(L)$ scaling of half-chain entanglement. We explain these scaling regimes analytically using an SU(2)-symmetric "Page law" and a mapping to loop models with crossings.

15 min. break

TT 19.8 Tue 11:30 H37

Generalized dual-unitary circuits from biunitarity — •Michael A. Rampp, Suhail A. Rather, and Pieter W. Claeys — Max-Planck-Institut für Physik komplexer Systeme, Dresden

We present a general framework for constructing solvable lattice models of chaotic many-body quantum dynamics with multiple unitary directions using biunitary connections. We show that a network of biunitary connections on the Kagome lattice naturally defines a multi-unitary circuit, where three 'arrows of time' directly reflect the lattice symmetry. These models unify various constructions of hierarchical dual-unitary and triunitary gates and present new families of models with solvable correlations and entanglement dynamics. Using multilayer constructions of biunitary connections, we additionally introduce multilayer circuits with monoclinic symmetry and higher level hierarchical dual-unitary solvability and discuss their (non-)ergodicity. Our work demonstrates how different classes of solvable models can be understood as arising from different geometric structures in spacetime.

TT 19.9 Tue 11:45 H37

Magic spreading in doped Clifford circuits — •Jiangtian Yao and Pieter W. Claeys — Max Planck Institute for the Physics of Complex Systems

We study the spreading of magic, or nonstabilizerness, in Clifford circuits with doping by non-Clifford gates. We characterize the spatial extent of magic in classes of Clifford circuits where the growth behavior of entanglement entropy and operator strings are known. The dynamics of magic spreading in such circuits is compared to that of entanglement entropy, and quantitative measures for longer-ranged magic are also explored.

TT 19.10 Tue 12:00 H37

One magnon magnetization dynamics for the kagome lattice antiferromagnet — Henrik Schlüter, •Jannis Eckseler, and Jürgen Schnack — Faculty of Physics, Bielefeld University, Bielefeld, Germany

We present aspects of the one-magnon dynamics of the antiferromagnetic kagome lattice as an example of flat-band dynamics extending the work of [1] to two dimensional systems. We illustrate how localized eigenstates also called localized magnons [2] influence the dynamics of excitations and possibly prevent the system from thermalization. To this end we introduce a $J_1 - J_2$-model for the kagome lattice which guarantees the stability of one out of three localized magnons and lets us distinguish the different flat bands.

[1] F. Johannesmann, J. Eckseler, H. Schlüter, and J. Schnack, Phys. Rev. B 108, 064304 (2023).
[2] J. Schnack, H.-J. Schmidt, J. Richter, and J. Schulenburg, Eur. Phys. J. B 24, 475 (2001).

TT 19.11 Tue 12:15 H37

Towards a Many-Body Generalization of the Wigner-Smith Time Delay — •Georg Maier[1], Carolyn Echter[2], Juan Diego Urbina[1], Caio Lewenkopf[3], and Klaus Richter[1] — [1]Institut für Theoretische Physik Universität Regensburg, Regensburg, Germany — [2]Mathematische Fakultät Universität Regensburg, Regensburg, Germany — [3]Instituto de Física Universidade Federal Fluminense, Niterói RJ, Brazil

Many body systems with a large number of degrees of freedom are usually described by statistical physics on the theoretical side while experiments usually relay on scattering (e.g. particle physics). Is it possible to relate scattering and statistical physics, or to measure scattering-related observables which directly relate to quantities of statistical physics? At least for single particle systems a close relation exists between the well known Wigner-Smith delay time in scattering theory and the density of states of the scattering system.

I will present a novel ansatz relating a many-body version of dwell-/Wigner-Smith delay time and many body density of states based on the famous Birman-Krein-Friedel-Loyd formula connecting scattering theory and statistical observables in the many-body context. Due to the flexibility of this ansatz it can be used to investigate a wide variety of MB systems. I will discuss interesting scaling behaviors for different systems, like the harmonic trap[1] or the free particle together with the different behavior of bosons, fermions and indistinguishable particles.

[1] C. Echter et. al 2409.08696

TT 19.12 Tue 12:30 H37

Subleading logarithmic behavior in the parquet formalism — •Marcel Gievers[1,2], Richard Schmidt[3], Jan von Delft[1], and Fabian B. Kugler[4] — [1]Ludwig-Maximilians-Universität, München — [2]Max-Planck-Institut für Quantenoptik, Garching — [3]Universität Heidelberg — [4]CCQ, Flatiron Institute, New York

The Fermi-edge singularity in x-ray absorption spectra of metals is a paradigmatic case of a logarithmically divergent perturbation series. Prior work has thoroughly analyzed the leading logarithmic terms. Here, we investigate the perturbation theory beyond leading logarithms and formulate self-consistent equations to incorporate all leading and next-to-leading logarithmic terms. This parquet solution of the Fermi-edge singularity goes beyond the previous first-order parquet solution and sheds new light on the parquet formalism regarding logarithmic behavior. We present numerical results in the Matsubara formalism and discuss the characteristic power laws. We also show that, within the single-boson exchange framework, multi-boson exchange diagrams are needed already at the leading logarithmic level.

TT 19.13 Tue 12:45 H37

Ballistic transport in a disordered, boundary-driven XXZ spin chain. — •Johannes S Hofmann[1], Adam McRoberts[2], and Roderich Moessner[1] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]International Centre for Theoretical Physics, Strada Costiera 11, 34151, Trieste, Italy

Recent experiments on Google's sycamore NISQ device on spin transport realised ballistic transport in a edge-driven XXZ chain without disorder; and theoretical works on the classical variant demonstrated the survival of ballistic regime in the easy-plane upon the introduction of bond disorder. Here, we consider various generalisations of this set-up.