DY 46: Many-body Quantum Dynamics I (joint session DY/TT)

Time: Thursday 9:30–12:45 Location: HÜL/S186

DY 46.1 Thu 9:30 HÜL/S186

Nonequilibrium transport in adaptive fermionic circuits — •Paul Weiss[1], Karim Chahine[2], and Michael Buchhold[1] — [1]Department of Theoretical Physics, Universität Innsbruck, Austria — [2]Institute for Theoretical Physics, University of Cologne, Germany

We investigate nonequilibrium dynamics in one-dimensional adaptive fermionic circuits, where monitored fermions undergo local unitary evolution conditioned on measurement outcomes. By tuning the measurement strength and the duration of the unitary gates, the dynamics can be continuously interpolated between incoherent, classical transport and coherence-dominated quantum transport. In the classical limit, we recover the asymmetric simple exclusion process (ASEP), while in the quantum regime we uncover a coherent analogue of the Burgers equation along with coherence-enhanced Kardar-Parisi-Zhang (KPZ) transport. Our analytical approach, based on transport equations and Keldysh field theory, is supported by numerical simulations.

DY 46.2 Thu 9:45 HÜL/S186

Frustration-Free Control and Absorbing-State Transport in Entangled State Preparation — •Tobias Dörstel[1,2], Thomas Iadecola[3,4,5], Justin H. Wilson[6,7], and Michael Buchhold[1,2] — [1]Department of Theoretical Physics, University of Innsbruck, Austria — [2]Institute for Theoretical Physics, University of Cologne, Germany — [3]Department of Physics, The Pennsylvania State University, USA — [4]Institute for Computational and Data Sciences, The Pennsylvania State University, USA — [5]Materials Research Institute, The Pennsylvania State University, USA — [6]Department of Physics and Astronomy, Louisiana State University, USA — [7]Center for Computation and Technology, Louisiana State University, USA

We study frustration-free control, a measurement-feedback protocol for quantum state preparation that extends the concept of frustration-free Hamiltonians to stochastic dynamics. The protocol drives many-body systems into highly entangled target states, common dark states of all measurement projectors, through minimal local unitary corrections that realize an absorbing-state dynamics without post-selection. We show that relaxation to the target state is governed by emergent transport of nonlocal charges, such as singlet excitations in SU(2)-symmetric dynamics. While measurement-feedback annihilates compatible charge configurations, both measurement and scrambling unitaries induce charge transport and thus determine the convergence time. Mapping a baseline model of SU(N) SWAP measurements with local corrections to a solvable absorbing random walk yields a runtime scaling $t \sim L^z$ with transport exponent $z = 2$.

DY 46.3 Thu 10:00 HÜL/S186

Quantum typicality approach to energy flow between two spin-chain domains at different temperatures — Laurenz Beckemeyer[1], •Markus Kraft[1], Mariel Kempa[1], Dirk Schuricht[2], and Robin Steinigeweg[1] — [1]University of Osnabrück, Department of Mathematics/Computer Science/Physics,D-49076 Osnabrück, Germany — [2]Institute for Theoretical Physics, Utrecht University, 3584CC Utrecht, The Netherlands

We discuss a quantum typicality approach to examine systems composed of two subsystems at different temperatures. While dynamical quantum typicality is usually used to simulate high-temperature dynamics, we also investigate low-temperature dynamics using the method. To test our method, we investigate the energy current between subsystems at different temperatures in various paradigmatic spin-1/2 chains, specifically the XX chain, the critical transverse-field Ising chain, and the XXZ chain. We compare our numerics to existing analytical results and find a convincing agreement for the energy current in the steady state for all considered models and temperatures.

[1] Beckemeyer et al. arXiv:2507.23439

DY 46.4 Thu 10:15 HÜL/S186

Revisiting boundary-driven method for transport: Finite-size effects and the role of system-bath coupling — •Mariel Kempa[1], Markus Kraft[1], Sourav Nandy[2], Jacek Herbrych[3], Jiaozi Wang[1], Jochen Gemmer[1], and Robin Steinigeweg[1] — [1]University of Osnabrueck, Osnabrueck, Germany — [2]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [3]Wroclaw University of Science and Technology, Wroclaw, Poland

Understanding transport in interacting quantum many-body systems is a central challenge in condensed matter and statistical physics. Numerical studies typically rely on two main approaches: Dynamics of linear-response functions in closed systems and Markovian dynamics governed by master equations for boundary-driven open systems. While the equivalence of their dynamical behavior has been explored in recent studies, a systematic comparison of the transport coefficients obtained from these two classes of methods remains an open question. Here, we address this gap by comparing and contrasting the dc diffusion constant $\mathcal{D}_{\mathrm{dc}}$ computed from the aforementioned two approaches. We find a clear mismatch between the two, with $\mathcal{D}_{\mathrm{dc}}$ exhibiting a strong dependence on the system-bath coupling for the boundary-driven technique, highlighting fundamental limitations of such a method in calculating the transport coefficients related to asymptotic dynamical behavior of the system. We trace the origin of this mismatch to the incorrect order of limits of time $t \to \infty$ and system size $L \to \infty$, which we argue to be intrinsic to boundary-driven setups.

DY 46.5 Thu 10:30 HÜL/S186

Synchronized Aharonov-Bohm Motifs via Engineered Dissipation — •Christopher Wächtler and Gloria Platero — ICMM-CSIC, Madrdi, Spain

The interplay between external gauge fields and lattice geometry can induce extreme localization dynamics through complete destructive interference. We show that combining this flux-induced localization with engineered dissipation leads to robust spin synchronization in rotationally symmetric spin geometries, referred to as Aharonov-Bohm motifs, with cyclic symmetries of any order. The synchronized dynamics is independent of initial conditions and features entanglement among spins within each motif. We further demonstrate that multiple motifs can fully synchronize when coupled, which is achieved by applying additional collective dissipation acting on all intra-motif spins. These results reveal a direct connection between flux-induced localization, dissipative engineering, and collective quantum synchronization.

DY 46.6 Thu 10:45 HÜL/S186

Krylov space dynamics of ergodic and dynamically frozen Floquet systems — •Luke Staszewski[1], Asmi Haldar[2], Pieter Claeys[1], and Alexander Wietek[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden — [2]Laboratoire de Physique Theorique - IRSAMC, Toulouse

In isolated quantum many-body systems periodically driven in time, the asymptotic dynamics at late times can exhibit distinct behavior such as thermalization or dynamical freezing. Understanding the properties of and the convergence towards infinite-time (nonequilibrium) steady states however remains a challenging endeavor. We propose a physically motivated Krylov space perspective on Floquet thermalization which offers a natural framework to study rates of convergence towards steady states and, simultaneously, an efficient numerical algorithm to evaluate infinite-time averages of observables within the diagonal ensemble. The effectiveness of our algorithm is demonstrated by applying it to the periodically driven mixed-field Ising model, reaching system sizes of up to 30 spins. Our method successfully resolves the transition between the ergodic and dynamically frozen phases and provides insight into the nature of the Floquet eigenstates across the phase diagram. Furthermore, we show that the long-time behavior is encoded within the localization properties of the Ritz vectors under the Floquet evolution, providing an accurate diagnostic of ergodicity.

15 min. break

DY 46.7 Thu 11:15 HÜL/S186

Chaotic many-body quantum dynamics, spectral correlations, and energy diffusion — •Dominik Hahn and John Chalker — Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Oxford OX1 3PU, United Kingdom

We present results on the quantum dynamics of a minimal model with spatial structure and local interactions. The model features a time-independent Hamiltonian, in contrast to the widely studied quantum circuits, and is analytically tractable in the limit of large local Hilbert space dimension and weak intersite coupling. In this regime, we show that the energy dynamics are governed by a classical master equation

exhibiting diffusive behavior. Furthermore, we demonstrate that the spectral form factor can be expressed exactly in terms of the solution to this master equation, demonstrating how the linear ramp emerges at long times, while locality gives rise to an additional enhancement at short times.

DY 46.8 Thu 11:30 HÜL/S186

Dissipative diffusion in quantum state preparation — •Tim Pokart[1], Lukas König[1], Sebastian Diehl[2], and Jan Carl Budich[1,3,4] — [1]Institute of Theoretical Physics, Technische Universität Dresden — [2]Institut für Theoretische Physik, Universität zu Köln, 50937 Cologne, Germany — [3]Würzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden, Germany — [4]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

Dissipative quantum protocols that engineer a desired state as their dark state provide a powerful route to preparing quantum many-body states. We investigate a number conserving variant of such a dissipative protocol which is able to stabilize a topologically nontrivial phase. We show that the protocol admits a unique and stable dark state. Furthermore, we find that the cooling is diffusive in nature, supported by both analytical arguments and numerical simulations.

DY 46.9 Thu 11:45 HÜL/S186

First principles simulation of spin diffusion using dynamic mean-fields — •Timo Gräßer[1], Matthias Ernst[1], and Götz S. Uhrig[2] — [1]Institute of Molecular Physical Science, ETH Zurich, 8093 Zurich, Switzerland — [2]Condensed Matter Physics, TU Dortmund University, 44227 Dortmund, Germany

The transfer of a globally conserved polarization among a homogeneous spin ensemble is called spin diffusion and one of the most important phenomena in the broad field of magnetic resonance. Describing spin diffusion theoretically is a notoriously difficult task due to the large number of spins involved. We use a description through dynamic mean-fields (dubbed spinDMFT [1]) to derive an effective model for spectral spin diffusion. The approach is benchmarked for two crystalline test samples, malonic acid and dipotassium α-D-glucopyranose-1-phosphate dihydrate, yielding a remarkable agreement with experimental data and requiring only little computational effort. This strongly supports the use of spinDMFT, which may be extended in future works to understand spin diffusion in dynamic nuclear polarization (DNP) experiments [2].

[1] T. Gräßer et al., Phys. Rev. Research 3, 043168 (2021), DOI 10.1103/PhysRevResearch.3.043168

[2] J. Eills et al., Chem. Rev. 123, 1417 (2023), DOI 10.1021/acs.chemrev.2c00534

DY 46.10 Thu 12:00 HÜL/S186

Simulating universal long-time dynamics in integrable quantum spin chains — •Angelo Valli[1], Catalin Pascu Moca[2], Miklos Antal Werner[3], Marton Kormos[1], Doru Sticlet[6], Balazs Dora[1], Ziga Krajnik[4], Tomaz Prosen[5], and Gergely Zarand[1] — [1]Budapest University of Technology and Economics, Budapest (Hungary) — [2]University of Oradea, Oradea (Romania) — [3]Wigner Research Centre for Physics, Budapest (Hungary) — [4]New York University, New York (USA) — [5]University of Ljubljana, Ljubljana (Slovenia) — [6]National Institute for R&D of Isotopic and Molecular Technologies, Cluj-Napoca (Romania)

We introduce a novel tensor-network approach to calculate cumulants of the full counting statistics to unprecedentedly long times. We investigate spin-transfer in quantum spin chains, where the superdiffusive transport with dynamical exponent z=3/2 has been conjectured to fall within the Kardar-Parisi-Zhang (KPZ) universality class of classical interface growth. Recent experimental evidence on quantum simulators challenged this hypothesis. Our results extend far beyond the experimental timescales and provide unambiguous evidence that spin transfer in integrable quantum spin chains is indeed incompatible with KPZ universality. However, spatio-temporal fluctuations of the spin analogue of surface roughness exhibit a self-similar Family-Vicsek (FV) scaling, relating roughness, growth, and dynamical exponents in all transport regimes and across models with SU(N) symmetry. Our results shed light on how classical universal scaling laws extend to the quantum many-body realm.

DY 46.11 Thu 12:15 HÜL/S186

Few-body structures of Quantum impurity problems in the Heisenberg picture — •Maxime Debertolis — University of Bonn

Quantum impurity problems are known to exhibit a simplified representation of their ground state or for quench protocols when an optimized single-particle basis is chosen. This work extends the study of single-particle rotations taylored to operators in the Heisenberg picture. We present the concept of natural super-orbitals for many-body operators, defined as the eigenvectors of the one-body super-density matrix associated with a vectorized operator. These objects are related to measures of non- Gaussianity of operators associated to the occupations of the natural super-orbitals. We perform a numerical investigation of the natural super-orbitals corresponding to both the time-evolution operator and a time-evolved local operator in the t-V model and in a quantum impurity model using tensor network simulations. In the quantum impurity model, occupations of the natural orbitals for both operators decay exponentially at all times. More surprisingly, the non-Gaussianity of the local operator saturates in time. This indicates that only a small number of orbitals contribute significantly to quantum correlations, enabling a compact matrix-product-operator representation. This framework opens the door to future research that leverages the compressed structure of operators in their natural super-orbital basis, enabling for instance the computation of out-of-time-order correlators in large interacting systems over extended time scales.

DY 46.12 Thu 12:30 HÜL/S186

Propagating the Hierarchical Equations of Motion (HEOM) using the Multi-Configurational Time-Dependent Hartree method (MCTDH) — •Luisa R. Grether[1], Uwe Manthe[2], Samuel L. Rudge[1], and Michael Thoss[1] — [1]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg im Breisgau, Deutschland — [2]Theoretische Chemie, Fakultät für Chemie, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Deutschland

The Hierarchical Equations of Motion (HEOM) are a powerful, numerically exact approach for simulating the time evolution of an open quantum system. Over the past decade, several tensor-train- and tensor-network-based approaches have been suggested and realized to make the HEOM applicable to ever larger model systems [1,2].

In this contribution, we build upon the existing twin-space formulation of the HEOM [2] and introduce a novel approach employing the Multi-Configurational Time-Dependent Hartree method (MCTDH) [3] for the time propagation of the HEOM. We demonstrate the applicability of the resulting HEOM+MCTDH method by presenting electron transport calculations for a nanojunction model, for which fully quantum results have not been available previously.

[1] Q. Shi *et al.*, J. Chem. Phys. **148**, 174102 (2018).
[2] Y. Ke *et al.*, J. Chem. Phys. **156**, 194102 (2022).
[3] H.-D. Meyer *et al.*, Chem. Phys. Lett. **165**, 73 (1990).