TT 63: Quantum Dynamics and Many-body Systems – Poster (joint session DY/TT)

Time: Wednesday 15:00–18:00 Location: P5

TT 63.1 Wed 15:00 P5

Operator spreading through the lens of the information lattice — •Luca Gawalleck[1,2], Maxime Debertolis[1], Jens H. Bardarson[3], and David J. Luitz[1] — [1]Institut of Physics, University of Bonn, Nußallee 12, 53115 Bonn, Germany — [2]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [3]Department of Physics, KTH Royal Insititute of Technology, Stockholm, 106 91 Sweden

We study the entanglement growth during Heisenberg time evolution by extending the framework of the information lattice to operators using the operator entanglement entropy. We focus on one-dimensional quantum spin chains and work in the tensor network formalism. The generalization of the information lattice to matrix product operators allows us to observe the spreading of initially local operators in a way that is not biased by the choice of a probing operator. We demonstrate that the operator information lattice we introduce contains all information typically provided by the out-of-time-order correlator with the additional ability to resolve the correlations on different scales. This method provides a good way to analyze systematically the time dependence of entanglement and can seamlessly be integrated into existing information-lattice-based algorithms.

TT 63.2 Wed 15:00 P5

Non-Perturbative Out-Of-Equilibrium Dynamics with Initial Four-Point-Correlations — Jürgen Berges, Louis Jussios, and •Cosima Schmitt — ITP Heidelberg

We investigate how initial correlations affect the equilibration dynamics of closed systems in quantum field theory. For interacting scalar fields with N components, we derive nonequilibrium evolution equations from a self-consistent large-N expansion to next-to-leading-order. By going beyond conventional Gaussian initial conditions, we point out the role of initial four-point correlations for the propagator evolution at early times and in the late-time approach to thermal equilibrium.

TT 63.3 Wed 15:00 P5

Nonequilibrium Green Function Simulations for Large Systems — •Erik Schroedter, Jan-Philip Joost, and Michael Bonitz — Christian-Albrechts-Universität zu Kiel, Kiel, Germany

Nonequilibrium Green Functions (NEGF) provide a powerful framework for accurately simulating the dynamics of correlated many-body systems. A major limitation of standard NEGF approaches is the cubic scaling of computational cost with the number of time steps. Recently, the G1-G2 scheme [1] overcame this limitation, achieving linear scaling. However, it introduces its own challenges, such as numerical instabilities at strong coupling and large memory requirements, which have so far restricted simulations to small systems with fewer than 150 basis states. Here, we introduce a NEGF-based quantum fluctuations approach (NEGF-QF)[2] that builds on earlier works [3] to efficiently factorize the two-particle Green function. This method drastically reduces computational costs for advanced self-energy approximations, including GW and T-matrix, while enabling straightforward parallelization. As a result, NEGF-QF allows simulations of systems with up to ten thousand basis states. We demonstrate the approach for large Hubbard clusters and graphene nanoribbons, illustrating its effectiveness for large, strongly correlated systems.

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[1] Schlünzen et al., Phys. Rev. Lett. 124, 076601 (2020)
[2] Schroedter et al., to be published (2026)
[3] Schroedter et al., Cond. Matt. Phys. 25, 23401 (2022)

TT 63.4 Wed 15:00 P5

Quantum Chaos in a Classical Counterpart to the Fermi-Hubbard model through an exact Path-Integral Formalism — •Louis Renck[1], Wolfgang Hogger[2], Juan Diego Urbina[2], and Peter Schlagheck[1] — [1]IPNAS, CESAM research unit, Université de Liège, Belgium — [2]Institut für Theoretische Physik, Universität Regensburg, Germany

Understanding quantum chaos in interacting many-fermion systems remains challenging : unlike many-bosons systems - where quantum-classical correspondence can be established using semiclassical tools such as the van Vleck-Gutzwiller propagator [1] -, most interacting fermions models still lack a sensible classical limit where Hamiltonian chaos can be defined.

We propose a candidate to the first classical Hamiltonian for the Fermi-Hubbard model with integrability broken by a random onsite potential. Starting from the fermionic Hamiltonian, we apply a Jordan-Wigner transformation and switch to the Schwinger-boson representation to obtain a bosonic form. A recently developed exact bosonic path-integral formalism [2] then provides a classical Hamiltonian symbol defined over a symplectic phase space. We investigate the resulting quantum-classical correspondence by comparing the effective dynamics with the quantum evolution, and we present quantitative checks of chaos based on spectral properties and out-of-time ordered correlators.

[1]. T. Engl, J. Dujardin, A. Argüelles, P. Schlagheck, K. Richter, and J. D. Urbina, Phys. Rev. Lett. 112, 140403 (2014).
[2]. F. Bruckmann and J. D. Urbina (2018)

TT 63.5 Wed 15:00 P5

Adaptive Fermion Circuits with chiral transport — •Markus Siegl and Michael Buchhold — Department of Theoretical Physics, Universität Innsbruck, Austria

Nonequilibrium quantum transport, where coherent many-body dynamics coexist with directional motion remains a central challenge in modern quantum physics. This project investigates transport phenomena in two coupled fermionic chains designed to break chiral symmetry. Using fermionic adaptive circuits and measure-ment-feedback protocols, we aim to control nonequilibrium dynamics and induce directional motion in an other-wise symmetric quantum system. By linking classical universality, quantum many-body effects, and information transport, the research seeks to uncover new mechanisms for controlled, symmetry-broken quantum transport, establishing a model system for genuinely nonequilibrium quantum matter.

TT 63.6 Wed 15:00 P5

Absorbing-State Dynamics and Feedback Control in Quantum Many-Body Scar Systems — •Lara Schorr — University of Innsbruck

We look at quantum many-body scar states, which are special excited states in non-integrable systems that do not thermalize. To better understand their non-equilibrium dynamics, we translate the problem to a measurement-based quantum circuit equipped with feedback control. Focusing on a spin-1/2 chain with SU(2) symmetry, we show that local unitary feedback enables controlled manipulation of non-local charges, allowing the system to relax into highly entangled dark states. By analyzing the convergence towards the target state, we find that the dynamics resembles an emergent absorbing-state process, in which non-local charges diffuse and annihilate over time. Studying the scaling of convergence times allows us to identify conditions under which the dynamics may exhibit an absorbing-state phase transition.

TT 63.7 Wed 15:00 P5

Floquet-Magnus expansion for driven quantum systems and spin dynamic mean-field theory in NMR — •Antonia Joëlle Bock — TU Dortmund University, Germany

An accurate and reliable theoretical description of periodically driven quantum systems is highly relevant to many applications, such as for magic-angle spinning (MAS) in nuclear magnetic resonance (NMR) and ultracold atoms in driven optical lattices. Typically, the first step in capturing the dynamics is to determine an effective time-independent Hamiltonian, for which one can choose from a broad range of slightly different, hence often confusing, theories. Thus, I specifically investigated two widely used theories: Average Hamiltonian theory (AHT) and the Floquet-van Vleck approach (secular averaging). I was able to quantify the importance of the kick operator for the equivalence between perturbative and numerically exact approaches. This was achieved through analytical calculations and numerical evaluations of exemplary spin systems. These crucial insights then build the foundation for the second step of my project: a dynamic mean-field theory for dense spin ensembles applicable to complex couplings between three or more spins (MAS-DMFT). The recently developed spinDMFT (cp., e.g., Gräßer et al., 2024) has proven to be efficient, accurate and applicable to large spin systems yielding 2-particle interactions.

TT 63.8 Wed 15:00 P5

Phonon mediated indirect spin interaction — •Pablo Reiser and Habib Rostami — University of Bath, Bath, United Kingdom

Due to the lack of inversion symmetry in the hBN monolayer, circular polarized vibration in solids, or chiral phonons, with nonzero angular momentum are allow. These chiral phonons can couple to spins of different nature through their angular momentum. Within this context, we explored the coupling of chiral phonons with non-zero angular momentum to two impurities spins in hBN. Using field theory methods, we obtained the spin susceptibility and studied it*s properties like the mass dependence of the coupling, frequency of oscillation and rate of decay. The momentum transfer due to this coupling may opens the door for non-trivial thermal or spin transport effects.

TT 63.9 Wed 15:00 P5

Dynamical Phases and Instabilities in Periodically Driven Bogoliubov-de Gennes Superconductors — •Subhadip Chakraborty, Animesh Panda, and Ferdinand Evers — Institute of Theoretical Physics, University of Regensburg, D-93040 Regensburg, Germany

We investigate the nonequilibrium dynamics of a superconductor subjected to a periodic modulation of the interaction strength starting with Bogoliubov-de Gennes (BdG) mean field Hamiltonian. Using numerical solutions of the time-dependent Bogoliubov-de Gennes equations, we first explore several dynamical superconducting regimes. Our analysis reveals a rich variety of phases, including Rabi-Higgs oscillations, synchronized Higgs dynamics, and time-crystalline responses, and shows how their stability varies across driving parameters. In some regions of parameter space, infinitesimal initial seeds of finite momentum pairing grow exponentially during our driving protocol. By computing the momentum-resolved pairing response, we identify the instability bands associated with these finite-momentum modes, quantify their growth rates, and determine their dependence on driving frequency and drive amplitude. These results provide a comprehensive numerical characterization of the dynamical phases and instabilities that arise in periodically driven superconductors before the final steady state is reached.

TT 63.10 Wed 15:00 P5

Higher order Magnus expansion for two-level quantum dynamics — •Chen Wei and Frank Grossmann — Institut für Theoretische Physik, 01062 Dresden, Germany

This study investigates the Magnus expansion[1] for a generic time-dependent two-level system. By using its convergence condition[2], we find that elementary unitary transformations significantly extend the validity of the Magnus expansion. Furthermore, higher order terms admit particular physical interpretations. By virtue of su(2) Lie algebra, the expansion is decomposed into a commutator-free form. To illustrate its usefulness, we study the Landau-Zener[3] model, which displays a special case of non-adiabatic transitions. Using agian the Magnus expansion, Hermitian and non-Hermitian versions of the semiclassical Rabi model are systematically treated by determining the Floquet quasienergy[4] and Bloch-Siegert shift[5]. As a noteworthy by-product, the Magnus expansion provides a quantitative characterization of the adiabatic theorem[6].

[1] W. Magnus, Commun. Pure Appl. Math. 7, 649-673 (1954). [2] M. M. Maricq, J. Chem. Phys. 86, 5647-5651 (1987). [3] C. Zener and R. H. Fowler, Proc. R. Soc. Lond. A 137, 696-702 (1932). [4] J. H. Shirley, Phys. Rev. 138, B979 B987 (1965). [5] F. Bloch and A. Siegert, Phys. Rev. 57, 522-527 (1940). [6] M. Born and V. Fock, Z. Phys. 51, 165-180 (1928).

TT 63.11 Wed 15:00 P5

Distribution of complex amplitudes of chaotic resonance states — •Jan Möseritz-Schmidt and Roland Ketzmerick — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

Resonance states of chaotic scattering systems have complex amplitudes in the position representation. Naively, one would expect that the phase of the complex amplitude is uniformly distributed, however, we observe significant deviations. We find that part of this is a finite-size effect which is already present in the random wave model. It is enhanced by the multifractal structure of chaotic resonance states, which follows from the factorization conjecture. We quantify these deviations using the phase rigidity and analyze its scaling behavior in the semiclassical limit. Numerically, this is demonstrated for the paradigmatic three-disk scattering system.

TT 63.12 Wed 15:00 P5

Complex dynamics and particle-wave correspondence in anisotropic mesoscopic cavities — •Silvan Stopp, Samuel Schlötzer, Lukas Seemann, and Martina Hentschel — Technische Universität Chemnitz, 09107 Chemnitz, Germany

Mesoscopic billiard systems with different geometries are well-known model systems for investigating complex dynamics and quantum chaos. While the breaking of spatial cavity symmetries is typically considered to be the origin of chaotic dynamics, we show that anisotropies, i.e., broken symmetries in momentum space, can also cause chaotic particle dynamics. To this end, we investigate bilayer graphene systems (BLG) [1] and birefringent optical microcavities [2], both of which have preferred propagation directions. Anisotropy prevent angular momentum to be a conserved quantity, and consequently, the angles of incidence and of reflection of a particle trajectory deviate. Therefore, we implementing an advanced ray tracing algorithm that we apply to BLG and birefringent cavities. We show that the presence of anisotropies induces chaotic dynamics even in circular cavities. We investigate the interplay of the cavity shape and the Fermi line geometry and illustrate how it affects the cavity dynamics. In particular, we find that certain trajectories can be stabilized by matching the symmetry in real and momentum space. In addition, we use Kwant and transformation optics to demonstrate ray/particle-wave correspondence in real space as well as in phase space using the Husimi function.

[1] L. Seemann, A. Knothe, M. Hentschel, PRB 107, 205404 (2023)
[2] M. Hentschel, S. Schlötzer, L. Seemann, Entropy 27(2):132 (2025)

TT 63.13 Wed 15:00 P5

Periodic orbit theory approach for a non-Hermitian Riemann operator — •Sebastian Hörhold, Andreas Hötzinger, Juan Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

The Riemann Hypothesis (RH) is one of the most important open problems in mathematics. Among the various approaches toward its proof is the Hilbert-Pólya (HP) conjecture, stating that there should exist a Hermitian operator whose eigenvalues t_n are given by the zeros of the Riemann zeta function $\zeta(1/2 + it_n)$. The RH would then follow from the reality of these eigenvalues.

In a recent contribution toward a proof of the RH, a non-Hermitian Hamiltonian has been introduced, referred to as a Riemann operator, whose spectrum contains the t_n, and from which one can construct an HP operator [1]. Our work focuses on a similar Hamiltonian, and we intend to make use of semiclassical tools to support earlier work by Berry and Keating, who obtained a formal asymptotic expression for the counting function of the nontrivial Riemann zeros [2]. Their results suggest a strong connection between the spectral statistics of these zeros and classically chaotic systems.

In this poster contribution, we show the emergence of the Riemann zeros within the spectrum of our non-Hermitian Hamiltonian and discuss how periodic orbit theory can be applied.

[1] E. Yakaboylu, arXiv:2408.15135
[2] M. V. Berry and J. P. Keating, SIAM Review 41.2 pp. 236-266

TT 63.14 Wed 15:00 P5

Echo state network prediction of billiard dynamics — •Anna Skopnik, Lukas Seemann, and Martina Hentschel — Institut für Physik, TU Chemnitz, Germany

Machine Learning has attracted a lot of interest recently. Here, we apply an Echo State Network (ESN) algorithm to two mesoscopic billiard systems in order to explore its usability in the prediction of the internal dynamics of ballistic cavities. First, we study the well-known Limaçon system with chaotic dynamics. Second, we study the more complex dynamics in an anisotropis system inspired by bilayer graphene (BLG) representing a mixed space dynamics with regular and chaotic trajectories. Here, we present preliminary results on the training and hyperparameter optimization for both systems, Limaçon and BLG.

TT 63.15 Wed 15:00 P5

Anomalous Dynamics in Complex Quantum Systems — •Irina Petreska[1], Pece Trajanovski[1,2], Ervin Kaminski Lenzi[3], and Trifce Sandev[1,2,4] — [1]Ss. Cyril and Methodius University in Skopje, Macedonia — [2]Macedonian Academy of Sciences and Arts, Skopje, Macedonia — [3]Universidade Estadual de Maringá, Maringá, Brazil — [4]Korea University, Seoul, Korea

We will give an overview of our recent works related to some generalizations of the Schrödinger equation. Special attention will be paid to the fractional Schrödinger equation, pointing out physical examples where the time-fractional Schrödinger equation naturally emerges under certain geometric constraints. Additionally, we include a long-range interaction term, modeled by an integral operator, which captures spatial nonlocalities. Using the Green's function approach, we derive analytical solutions and explore their implications in the time-space domain. Our findings reveal anomalous behavior arising from the interplay of fractional dynamics, nonlocal potentials and memory effects.