DY 53: Poster: Quantum Dynamics, Chaos and Information; Many Body Systems

Time: Thursday 15:00–18:00 Location: P1A

DY 53.1 Thu 15:00 P1A

Thermalization properties of a system with topological flat bands and impurities — •Stefan kleine Brüning and Thomas Dahm — Universität Bielefeld

Topological insulators posses edge states, which are gapless in contrast to the bulk states. Bi_2Se_3 is of particular interest, because of its relatively simple Hamiltonian and, most importantly, under the influence of a Zeeman field flat bands appear in thin stripes of this material[1].

Due to the zero group velocity of electrons in flat bands there is no thermalization for a localized initial state. The question arises how this non-thermalization behaviour and the localization changes in the presence of impurities. In this work we focus on disorder, which modifies the on-site energy of the material. The influence of this disorder is investigated numerically using time evolution. The observable of interest is a quantity which is related to the localization of the wavepacket. The behaviour of this observable under change of strength and number of impurities is compared to a situation without a flat band. To investigate the question of thermalization it is probed whether the eigenstate thermalization hypothesis holds. To do this we employ a method suggested by Steinigeweg et al.[2]. This method uses random state vectors and scaling behaviour to decide this matter.

[1] Paananen, T., & Dahm, T. Physical Review B, 87, 195447(2013).
[2] Steinigeweg, R., et al. Physical Review Letters, 112, 130403 (2014).

DY 53.2 Thu 15:00 P1A

Wave Functions in White Noise Potential: Spreading or Localization? — •Marco Hofmann and Barbara Drossel — Institute of Condensed Matter Physics, Technische Universität Darmstadt, Hochschulstr. 6, 64289 Darmstadt, Germany

We study the dynamics of a quantum wave function on a 1D lattice subject to a fluctuating potential that is described as uncorrelated Gaussian white noise. Starting from a stochastic Schrödinger equation, we derive the corresponding Lindblad equation. This Lindblad equation, in turn, can be unravelled in terms of stochastic wave function dynamics in several different ways, all of which are empirically equivalent, as the density matrix alone determines the outcome of measurements. Two of these unravellings are widely used in the theory of Open Quantum Systems, namely the Quantum State Diffusion Model and the Quantum Jump Method. We show that the degree of localization or spreading of the wave function depends on the type of unravelling used, and in particular on the way the trace-conserving term of the Lindblad equation is implemented in the wave function dynamics. Part of the implementations lead to the localization of the wave function on a limited number of lattice sites. Our results raise interesting questions related to the interpretation of the wave function.

DY 53.3 Thu 15:00 P1A

Sources and coupling in billiards for light — •Marika Federer, Rebecca Cizek, Michel Hendriks, Jule Katharina Schnepfer, Martí Bosch, Jakob Kreismann, Jaewon Kim, and Martina Hentschel — Institute of Physics, Technical University Ilmenau, Germany

Optical microresonators, or billiards for light, have proven to be a rich model system for nonlinear dynamics, quantum chaos, and optics. Here, we study how the presence of sources affects the intracavity dynamics and the far-field emission of these open systems. To this end, we use ray modelling as well as wave simulations and compare their results in the spirit of ray-wave correspondence in real and phase space. Furthermore, we relate the presence of sources to coupling phenomena and study coupled microcavities in arrays and how coupling affects the emission properties of the complex optical system.

DY 53.4 Thu 15:00 P1A

A PT-Symmetric Kicked Rotor — •Joseph Hall and Eva-Maria Graefe — Imperial College, London, UK

PT-symmetric quantum mechanics has attracted a large amount of research interest over the last decade. Thus far most theoretical investigations have focused on simple model systems, which are open counterparts of integrable and often even analytically solvable systems. However little investigation has been undertaken into the properties of PT-symmetric chaotic systems. Here we investigate this phenomenon for the example of a PT-symmetric generalisation of the kicked rotor. We present signatures of chaos arising in both the classical and quantum descriptions of the system.

DY 53.5 Thu 15:00 P1A

Structure of resonance eigenfunctions for chaotic systems with partial escape — •Konstantin Clauss[1], Eduardo Altmann[2], Arnd Bäcker[1,3], and Roland Ketzmerick[1,3] — [1]TU Dresden, Institut für Theoretische Physik — [2]School of Mathematics and Statistics, University of Sydney — [3]MPI für Physik komplexer Systeme, Dresden

Physical systems are often neither completely closed nor completely open, but instead they are best described by dynamical systems with partial escape or absorption. We introduce classical measures that explain the main properties of resonance eigenfunctions of chaotic quantum systems with partial escape [1]. We construct a family of conditionally-invariant measures with varying decay rates by interpolating between the natural measures of the forward and backward dynamics. We show numerically, that these classical measures describe the main features of quantum resonance eigenfunctions: their multifractal phase space distribution, their product structure along stable and unstable directions, and their dependence on the decay rate. The (Jensen-Shannon) distance between classical and quantum measures goes to zero in the semiclassical limit for long- and short-lived eigenfunctions, while it remains finite for intermediate cases.

[1] K. Clauß, E. G. Altmann, A. Bäcker, and R. Ketzmerick, Phys. Rev. E **100** (2019), 052205.

DY 53.6 Thu 15:00 P1A

Real-time dynamics and thermalization of quantum-classical hybrid systems — •Nicolas Lenzing and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

The real-time dynamics of a noninteracting system of fermions is strongly constrained due to a macroscopically large number of conserved quantities such that thermalization of the system in the long-time limit is generally not expected.

We test this expectation for a slightly different setup, namely by coupling a classical degree of freedom to the Fermi-gas system, i.e., we consider fermions confined by an infinite potential well and treat one of the “walls” as a classical dynamical variable.

The time-dependent wall position is governed by a Newtonian equation of motion, including the Fermi-gas pressure, which must be solved simultaneously with the von-Neumann-type equation of motion for the one-particle reduced density matrix of the Fermi subsystem.

In a first step, we discuss fundamental aspects of the dynamics of quantum-classical hybrid systems for the case of a single quantum particle in contact with the classical wall.

In a second step, we study the time evolution towards a thermal state for the case of a Fermi gas in contact with a classical wall which is additionally subjected to an external force and compare with the predictions of thermodynamics.

DY 53.7 Thu 15:00 P1A

Violation of eigenstate thermalization in an interacting flat-band system — •Mirko Daumann and Thomas Dahm — Universität Bielefeld, Germany

Flat-band systems are characterized by the presence of completely dispersionless bands. They have interesting properties, because they possess a macroscopic degeneracy, zero group velocity and infinite effective mass. Recently, flat bands have been realized experimentally in various different physical systems.

Here we investigate the role of a particle-particle interaction on the thermalization in a quasi one-dimensional flat band system. By time evolution, we show that thermalization is not reached both in terms of the inverse participation ratio (IPR) and local operator expectation values. We further validate our results by showing that our system violates the eigenstate thermalization hypothesis (ETH) even in the presence of a particle-particle interaction.

DY 53.8 Thu 15:00 P1A

Fermionic duality beyond weak coupling: General simpli-

fications of open-system dynamics — •Valentin Bruch[1], Konstantin Nestmann[1], Maarten Wegewijs[1,2,3], Jens Schulenborg[4], and Janine Splettstoesser[5] — [1]Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany — [2]JARA-FIT, 52056 Aachen, Germany — [3]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [4]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen — [5]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, SE-41298 Göteborg

The dynamics of a large class of open fermionic quantum systems with strong memory effects obeys an exact relation known as "fermionic duality". These are essentially impurity-type quantum transport models with arbitrarily complex and strong local interactions exhibiting various low-temperature many-body effects. Here we present a new, more elementary derivation of this and extend it to all prominent approaches to open system dynamics, including the time-nonlocal (Nakajima-Zwanzig) and the time-local (TCL) quantum master equation with its generalized Lindblad form, and the Kraus operator decomposition. Whereas in some of these formulations this yields a strong restriction on eigenvalues and eigenvectors, in others it can be exploited to completely by-pass nontrivial time-evolution calculations. This establishes that for fermionic open systems there exists a powerful analogue of the symmetry of hermitian conjugation in closed systems.

DY 53.9 Thu 15:00 P1A

Many-Body Localization in the Hartree-Fock Approximation

— •Paul Pöpperl[1], Elmer Doggen[2], Konstantin Tikhonov[2], Igor Gornyi[1,2], and Alexander Mirlin[1,2] — [1]Institut für Theorie der kondensierten Materie, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

We investigate the quench dynamics of a spinless disordered Fermi-Hubbard model in the Hartree-Fock (HF) approximation. The one-dimensional model is expected to show a transition to a many-body localized (MBL) phase with increasing disorder at a fixed interaction strength. Surprisingly, the simple HF approximation qualitatively captures the MBL phenomenology [1]. We compare results from the HF approach to exact calculations and results obtained by the time-dependent variational principle (TDVP) [2] in order to illuminate the benefits and limitations of the HF approach.

[1] Weidinger, Simon et al (2018).
Self-consistent Hartree-Fock approach to many-body localization.
Physical Review B. 98. 10.1103/PhysRevB.98.224205.
[2] Doggen, Elmer V. H. et al (2018).
Many-body localization and delocalization in large quantum chains.
Physical Review B. 98. 10.1103/PhysRevB.98.174202.

DY 53.10 Thu 15:00 P1A

Prediction of Floquet oscillations and Zitterbewegung in driven Dirac systems

— •Vanessa Junk, Phillipp Reck, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg

The modification of solid state systems by time periodic driving has been a very vivid research topic in the last years. A special proof of Floquet engineering's power was the discovery of Floquet topological insulators [1]. However, the search for similarities between Bloch and Floquet systems is still ongoing.

Here, we predict an analogue of Bloch oscillations [2] occuring in Floquet systems. We numerically demonstrate these Floquet oscillations in a spatially continuous but time-periodically driven Dirac system [3]. A particle is driven through the resulting Floquet band structure by a static electric field and performs a motion similar to Bloch oscillations. Since the features of the Floquet bands are mimicked by these oscillations, the latter could provide a way to directly measure the Floquet bands. Due to the Dirac character of our model system, we can also observe Zitterbewegung with frequency equal to the energy difference of the Floquet bands.

[1] N. H. Lindner, G. Refael, and V. Galitski, Nature Physics **7**, 13368 (2016)
[2] K. Leo, P. Haring Bolivar, F. Brüggemann, R. Schwedler, and K. Köhler, Solid State Comm. **84**, 943 (1992)
[3] V. Junk, P. Reck, C. Gorini, and K. Richter, arXiv:1906.04446v1

DY 53.11 Thu 15:00 P1A

Dynamics of visons in weakly perturbed Kitaev models

— •Aprem Joy and Achim Rosch — Institute of Theoretical Physics, University of Cologne, Germany

The Kitaev honeycomb model is a paradigmatic model which realizes a spin liquid phase and is exactly solvable. Candidate materials for Kitaev spin liquids are best described by Kitaev interactions perturbed by other spin exchange couplings which breaks the exact solvability of the model.

We study the dynamics of topological vison excitations coupled to the Majorana fermions in the Kitaev honeycomb model under weak perturbations, e.g., Heisenberg coupling, magnetic field and symmetric-anisotropic (Γ) interactions. The pure Kitaev model can be exactly solved thanks to the underlying static nature of the visons which effectively separates the model into free majoranas hopping in the background of a static Z_2 gauge field. But in the presence of perturbations, these visons are no more static but acquire dynamics also modifying the Majorana sector.

DY 53.12 Thu 15:00 P1A

Interplay of quantization and chaotic behaviour in ring-coupled condensates

— •Damian Wozniak[1,2], Johann Kroha[3], and Anna Posazhennikova[1,2] — [1]Institut für Physik, Universität Greifswald, 17487 Greifswald, Germany — [2]Department of Physics, Royal Holloway, University of London, Egham, Surrey TW20 0EX, United Kingdom — [3]Fachbereich Physik, Universität Bonn, D-53115 Bonn, Germany

We study large rings of weakly-coupled Bose-Einstein condensates and analyse in detail their dynamics and its dependence on the system size. Since we are interested in circulating currents and their quantisation, we consider initial conditions which result in potential maximisation of such current: equal site occupation and equal phase differences between neighbouring sites. Within the Gross-Pitaevskii approximation we show that the current is quantised (exhibits sharp delta peaks) if the phase difference takes certain discrete values in the interval (Pi/2; 3Pi/2). The peaks, however, gradually average out to zero with increasing interaction due to chaos inherent to the system of many condensates. This kind of behaviour does not happen for smaller phase differences because of energetic reasons. Eventually, the quantisation ceases to occur for a macroscopic number of sites and the circular current manifests sinusoidal behaviour readily derived from the noninteracting limit. This marks the transition to the continuous limit.

DY 53.13 Thu 15:00 P1A

Partial transport barriers in 4D symplectic maps

— •Markus Firmbach[1], Arnd Bäcker[1,2], and Roland Ketzmerick[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

The transport across partial barriers in systems with a higher-dimensional phase space is of great interest for physical applications as well as from a conceptual point of view. We consider the 4D standard map and construct partial transport barriers of co-dimension one which are based on invariant objects in phase space, namely families of periodic one-tori. We compute the 4D flux across these partial barriers by volume- and transport measurements. This agrees with a flux formula using just the invariant objects.

DY 53.14 Thu 15:00 P1A

Entanglement in integrable-chaotic bipartite systems

— •Maximilian Kieler[1] and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

We investigate entanglement of eigenstates and time-evolved states for the four-dimensional coupled quantum standard map where one subsystem is integrable and the other is chaotic. An analytic description of the eigenstate transition from unentangled to entangled is governed by a single transition parameter. The time evolution is investigated with respect to the initial state ensembles of unperturbed eigenstates, random states, and coherent states. Each ensemble exhibits different initial time behaviour and asymptotic values of the entropy.

DY 53.15 Thu 15:00 P1A

Entanglement in coupled kicked tops with chaotic dynamics

— •Tabea Herrmann[1], Maximilian Kieler[1], Felix Fritzsch[1], and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

The entanglement of eigenstates in two coupled, classically chaotic kicked tops is studied in dependence of their interaction strength. Governed by a universal scaling parameter, the statistics of level spacings, entanglement entropies, and the Schmidt eigenvalues undergo a transition from the non-interacting system towards full random matrix behavior [1]. Universality is found not only for equally sized large subsystems but also when one subsystem is small. Introducing a suitable random matrix transition ensemble allows for deriving the transition parameter. Combining the random matrix approach with perturbation theory leads to an accurate description of the initial phase of the transition. In the case of the entanglement entropies this can be extended to the whole transition.

[1] arXiv:1910.13447 [quant-ph] (2019)

DY 53.16 Thu 15:00 P1A

Resonance–Assisted Tunneling in Deformed Optical Microdisks with a Mixed Phase Space — •Felix Fritzsch[1], Roland Ketzmerick[1,2], and Arnd Bäcker[1,2] — [1]TU Dresden, Institut für Theoretische Physik — [2]MPI für Physik komplexer Systeme, Dresden

In optical microcavities dynamical tunneling allows for finite lifetimes of whispering gallery modes, which are classically confined by total internal reflection. The lifetimes of such modes may drastically decrease by resonance–assisted tunneling due to the presence of classical nonlinear resonances in the ray dynamics. We present an intuitive semiclassical description which is based on classical properties and gives good agreement with numerically obtained lifetimes [1]. Moreover, we employ a perturbative description of resonance–assisted tunneling in order to predict complex wave numbers and to reconstruct both the intensity distribution of the nearfield as well as the phase-space distribution of whispering gallery modes.

[1] Fritzsch, Ketzmerick, Bäcker, Phys. Rev. E **100**, 042219 (2019)

DY 53.17 Thu 15:00 P1A

Relaxation dynamics in a Hubbard dimer coupled to fermionic baths: phenomenological vs. microscopic description — •Eric Kleinherbers[1], Nikodem Szpak[1], Jürgen König[1], and Ralf Schützhold[2,3] — [1]Theoretische Physik, Universität Duisburg-Essen and CENIDE, Lotharstr. 1, 47048 Duisburg — [2]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden — [3]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden

We study relaxation dynamics in a strongly-interacting two-site Fermi-Hubbard model that is induced by fermionic baths. On the one hand, we model the dynamics with a Lindblad equation where the jump operators are chosen on pure phenomenogical grounds in the spirit of a local-bath approximation. On the other hand, we employ the real-time diagrammtic technique and derive the generalized master equation microscopically. Analyzing the characteristic time scales of relaxation processes, we find and discuss qualitative differences between the phenomenological and the microscopic approach. [1]

[1] E. Kleinherbers, N. Szpak, J. König, and R. Schützhold, arXiv: 1910:04130 (2019)

DY 53.18 Thu 15:00 P1A

Towards a numerical implementation of the Quench Action Approach — •Philipp Jaeger[1,2], Andreas Klümper[2], and Jesko Sirker[1] — [1]University of Manitoba, Department of Physics and Astronomy, Winnipeg, MB, Canada — [2]Bergische Universität Wuppertal, Fachbereich C - Fachgruppe Physik, Wuppertal, Germany

In the framework of integrable models the Quench Action approach was developed in recent years. This formalism in principle allows to calculate intermediate-time dynamics exactly by considering certain infinitesimal excitations around the GGE, all belonging to the same macro-state. However it is notoriously difficult to determine the relevant states and to evaluate the integrals. So far, this method has proven very useful to calculate GGE states and their convergence behaviour to the sub-leading order.

The two main ingredients are a spectrum and a measure of entropy, which can in principle be obtained using exact diagonalization (ED). To determine the relevant excitations, the n-String states from Bethe Ansatz must be identified in the numerics. To that end, we must consider sufficiently large systems which makes the ED algorithm quite complicated.

DY 53.19 Thu 15:00 P1A

Disentanglement Approach to Many-Body Quantum Spin Systems — •Stefano De Nicola — IST Austria

The disentanglement approach provides an exact description of many-body quantum spin systems in terms of classical variables. The resulting formulation can be equally seen as a field theory, amenable to analytical treatments, and a numerical method, whereby quantum dynamics is exactly mapped to an average over an ensemble of classical stochastic trajectories. The disentanglement method is applicable to integrable and non-integrable systems, including those in higher dimensions, within a unified framework, and can be applied both in and out of equilibrium. After discussing the general features of the disentanglement formalism, I illustrate the method by considering in particular its application to quantum quenches in paradigmatic many-body quantum spin systems. In this context, I show that the method can be used to obtain a wide range of observables, computed by numerically evaluating a set of formulae of broad applicability. Further insights on the quantum dynamics can be obtained by investigating the underlying quantum-to-classical correspondence, as recently shown in the case of dynamical quantum phase transitions. Finally, I discuss the strengths and limitations of the current implementation of the method, outlining directions for further developments.

DY 53.20 Thu 15:00 P1A

Performance of locally purified TN states as Ansatz-class for physical systems — •Lennart Bittel[1], Albert H. Werner[2], and Martin Kliesch[1] — [1]Heinrich Heine Universität, Düsseldorf, Germany — [2]University of Copenhagen, Copenhagen, Denmark

Tensor network models have proven to be a useful tool for the simulation of interacting quantum many-body systems and have also been extended from closed to open quantum systems. Matrix product density operators (MPDO) provide a common ansatz class to simulate quantum states under nearest neighbour Lindblad dynamics. Alternatively, locally purified tensor networks can be used to avoid positivity issues and to to obtain trace norm control for the simulation errors. However, It is known that some states can be approximated less efficiently compared to MPDO. Moreover, purifications of quantum states have a unitary gauge freedom, which can lead to significant errors in simulation if not appropriately fixed. In this work, we investigate use cases and develop algorithms for open tensor networks like state approximation, Lindblad dynamics and finding the respective equilibrium state and show that purified networks can outperform MPDO for relevant physical systems.

DY 53.21 Thu 15:00 P1A

Rydberg Composites — •Matthew Eiles, Andrew Hunter, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, 38 Noethnitzer Str. Dresden 01187

Rydberg states of atoms can be large enough that, in a dense cloud of ground state atoms, the electron can scatter off of many hundreds of impurities. Such a system, combining a Rydberg atom with a dense environment of localized scatterers, is called a Rydberg Composite. In conjunction with the high degeneracy of electronic states, the scattering from the localized impurities leads to a variety of heavily perturbed electronic states which, since the impurity atoms can be arranged in either crystalline or amorphous structures, shares many similarities with phenomena in solid-state materials. We will discuss some of these properties in this poster, for example the appearance of a band-like structure in the electronic density of states in a two-dimensional Composite and the existence of Anderson localization in a circular Composite.