TT 99: Quantum Chaos and Coherent Dynamics (joint session DY/TT)

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

TT 99.1 Fri 9:30 HÜL/S186

Time reversal invariance breaking in quantum chaotic scattering — •Ahmed Aldabag, Nils Gluth, and Thomas Guhr — Universität Duisburg Essen

A. Aldabag, N. Gluth and T. Guhr, Universität Duisburg-Essen

Scattering theory is a key tool for the investigation of quantum systems. Often, the systems are stochastic or in a broad sense chaotic. Using Random Matrix Theory, our group recently derived the distributions of off-diagonal scattering matrix elements and cross sections with the Supersymmetry Method. We did that for the three Dyson classes which are distinguished by the presence or absence of time-reversal invariance in the system. In some important physics situations, time-reversal invariance is weakly broken. We succeeded in analytically calculating the corresponding effects on the universal behavior of the mentioned distributions. Our results provide new tools to analyze time-reversal invariance breaking in data from scattering experiments.

TT 99.2 Fri 9:45 HÜL/S186

Normalization of resonance states in chaotic scattering systems — •Florian Lorenz, Jan Möseritz-Schmidt, and Roland Ketzmerick — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

The normalization of resonance states in scattering systems poses a challenge due to their divergent asymptotic behavior. As a consequence, they cannot be normalized by the usual norm, but instead, by the overlap between left and right resonance states. For dielectric cavities, we demonstrate that this left-right overlap can be computed efficiently using a boundary integral, avoiding divergent integrands. This result provides a practical numerical tool for resonance state normalization. For example, this allows for exact time evolution of wave packets based on resonance states.

TT 99.3 Fri 10:00 HÜL/S186

How exceptional points conduct mode dynamics in optical microcavities — Tom Simon Rodemund[1], Chang-Hwan Yi[2], Jung-Wan Ryu[2], Síle Nic Chormaic[3], and •Martina Hentschel[1] — [1]Institut für Physik, TU Chemnitz, Germany — [2]PCS, IBS, Daejeon, Korea — [3]OIST, Okinawa, Japan

Optical microcavities confine light through total internal reflection, making them inherently open, non-Hermitian systems. Their resonances have a real and an imaginary part, both of which depend on external parameters such as the resonator geometry or the refractive index. When scanning the parameter space, resonances can coincide and when they do so in their real and imaginary part, they form an exceptional point. We illustrate their occurrence and consequences in mesoscopic optics in two examples. First, we consider two coupled two-dimensional microcavities over coupling distances of several resonance wavelengths. Their mode dynamics is determined by a chain of exceptional points that exhibit a periodicity of approximately the wavelength [1]. The second example is a three-dimensional truncated cone. We investigate the interaction between the two mode polarizations, TE and TM, and find that the mode character changes smoothly, with TE and TM coinciding at exceptional points [2]. We confirm this behavior in phase space by generalizing the concept of Husimi functions to three dimensions. [1] C.-H. Yi, J.-W. Ryu, T.S. Rodemund, and M. Hentschel, Phys. Rev. A 112, L031501 (2025). [2] T.S. Rodemund, S. Li, S. Nic Chormaic, and M. Hentschel, Phys. Rev. A 112, 033528 (2025).

TT 99.4 Fri 10:15 HÜL/S186

Describing the spectral behavior around higher-order exceptional points with "periodic orbits" — •Daniel Grom[1], Julius Kullig[1], Malte Röntgen[2], and Jan Wiersig[1] — [1]Institut für Physik, Otto-von-Guericke-Universität Magdeburg, 39016 Magdeburg, Germany — [2]Laboratoire d'Acoustique de l'Université du Mans, 72085 Le Mans, France

Coupled optical microrings can deliver a simple and robust scheme to generate higher-order exceptional points (EPs), where multiple eigenvalues and -modes coalesce. A feature of an EP of order n, is the high sensitivity of the eigenvalues to small perturbations. Two types of perturbations can be classified. The generic behavior, where the eigenvalue response is proportional to the nth root and the non-generic type with a different eigenvalue response.

We present a graph theoretical perspective on the spectral characterization of perturbed higher-order EPs. It turns out that specific "periodic orbits" within the graph picture of the non-chaotic system govern the eigenvalue behavior.

TT 99.5 Fri 10:30 HÜL/S186

Dynamic origin of quantum chaos signatures in the zeros of the Riemann zeta function by means of periodic orbit theory — •Andreas Hötzinger, Sebastian Hörhold, Juan Diego Urbina, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

In the 90's, Berry and Keating [1] provided a qualitative, semiclassical analogy to the counting function of the nontrivial Riemann zeros, i.e. the zeros of the famous zeta function (ZF) $\zeta(s)$. Similar to Gutzwiller's trace formula they obtain a result in which the primes play the role of periodic orbits and argue that the so-called Riemann dynamics, underlying the primes, should be chaotic. It is speculated that this system is the classical limit of a Hermitian quantum Hamiltonian which has eigenvalues coinciding with the nontrivial zeros of $\zeta(1/2 + it_n)$.

Recently, a promising candidate for such a Hamiltonian has been proposed [2], which has the potential to advance research toward a proof of the Riemann hypothesis. Based on these results, we use a related and simpler, yet non-Hermitian Hamiltonian and consider its semiclassical regime by employing methods from periodic orbit theory.

In this talk, we present our progress in the study of the classical limit of this operator and its dynamics in a complexified phase space. Through this, we hope to unveil a deeper relation between quantum chaos signatures of number theory encoded in the ZF with classical phase space structures.

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

TT 99.6 Fri 10:45 HÜL/S186

Semiclassical geometry of entanglement — •Maximilian Kieler and Peter Schlagheck — CESAM research unit, University of Liège, B-4000 Liège, Belgium

We propose a semiclassical perspective on entanglement in the form of a geometric Schmidt decomposition of regular states, e.g., states associated with invariant tori. Utilizing WKB quantization techniques and classical geometry, we derive the Schmidt spectrum and the corresponding Schmidt states. This framework allows for the reduction of the complexity in many-body states by decomposing them into lower-dimensional components.

15 min. break

Invited Talk TT 99.7 Fri 11:15 HÜL/S186

Anyon dynamics in driven topologically ordered quantum systems — •Francesco Petiziol — Technische Universität Berlin, Institut für Physik und Astronomie, Hardenbergstr. 36, 10623 Berlin

Quantum systems with topological order exhibit long-range entanglement and host quasiparticle excitations with unconventional quantum statistics – anyons. These features make them of great interest from both fundamental and quantum-technological perspectives. Recent progress in realizing topological order in quantum simulators highlights the importance and the challenge of understanding the behaviour of such systems under non-equilibrium conditions. Focusing on Kitaev's toric code, I will discuss how external driving, either coherent or incoherent, can impact and alter anyon properties. Examples include the emergence of more complex anyon classes from simpler ones, the dynamics of entanglement under driven anyon proliferation, and opportunities for controlled anyon transport.

TT 99.8 Fri 11:45 HÜL/S186

Floquet engineering in lattice systems with a parametrically modulated parabolic potential — •Usman Ali[1], Martin Holthaus[1], and Torsten Meier[2] — [1]Institut für Physik, Carl von Ossietzky Universität, D-26111 Oldenburg, Germany — [2]Department of Physics, Paderborn University, Warburger Strasse 100, D-33098 Paderborn, Germany

We present a route to Floquet engineering in lattice systems that exploits a parabolic potential to generate tunable slowly varying on-site energies. When a selected level spacing in the spectrum of the combined parabolic lattice is brought into near resonance with an external periodic drive, nonlinear resonances emerge in the classical phase space and reorganize quantum eigenstates into families of near-resonant Floquet states. Using a Mathieu-resonance approximation together with numerical Floquet calculations, we construct these states and demonstrate how resonant trap eigenstates transmute into resonance-induced effective ground states [1]. The long-time population and transport dynamics are strongly sensitive to the initial phase of the drive, providing a phase-dependent control knob for engineered tunneling and coherence. We identify parameter regimes accessible to present-day cold-atom experiments and argue that selectively populating these Floquet ground states provides a clean testbed for driven many-body and Floquet-band phenomena, enabling novel lattice dynamics inaccessible in solid-state materials [2]. References: [1] U. Ali, M. Holthaus, and T. Meier, New J. Phys. 26, 123016 (2024) [2] U. Ali, M. Holthaus, and T. Meier, Phys. Rev. Research 5, 043152 (2023)

TT 99.9 Fri 12:00 HÜL/S186

Transport through two Floquet-engineered Impurities in a One-Dimensional System: Coherent Control of Fano Resonances, BICs and Localization — •Vincenzo Bruno[1,2], Ameneh Sheikhan[1], Roberta Citro[2,3], and Corinna Kollath[1] — [1]Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany — [2]Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno and INFN, Via Giovanni Paolo II, 132, I-84084 Fisciano (Sa), Italy — [3]CNR/SPIN, Fisciano (Sa), 84098, Italy

Floquet engineering has attracted considerable attention due to its ability to coherently control quantum states, finding successful applications across a wide range of fields such as quantum materials, ultracold atoms, and cavity systems. We investigate particle transport through a one-dimensional system containing two periodically driven impurities. Such a configuration is highly relevant for experimental realizations ranging from ballistic semiconductor wires and electron optics to ultracold atoms, and exhibits remarkably rich transmission properties. A central feature of this system is the emergence of Fano resonances-phenomena arising from the quantum interference between a continuum scattering path and discrete quasi-bound states. We demonstrate how drive parameters can be tuned to dynamically control these resonances. Furthermore, we reveal the existence of Bound States in the Continuum (BICs) and explore the interplay between Fano interference and cavity modes. This interplay leads to a localization mechanism where the system can be switched from a fully localized state to a regime of perfect transparency.

TT 99.10 Fri 12:15 HÜL/S186

Ruelle-Pollicott signatures of unitary quantum systems — •Scott Daniel Linz, Jiaozi Wang, Merlin Füllgraf, and Jochen Gemmer — Department of Mathematics/Computer Science/Physics, University of Osnabrück, D-49076 Osnabrück, Germany

Phenomenological observations demonstrate that unitary quantum systems thermalize and equilibrate. While many concepts have been introduced to describe the equilibrium of a quantum system, the route to this state remains an area of ongoing research. A proposed step towards a general description of this behaviour is that correlation functions of chaotic quantum systems can be described by a superposition of relatively few damped oscillations, where each is weighted and assigned a complex frequency. These frequencies will be called Ruelle-Pollicott signatures after the well-understood Ruelle-Pollicott resonances that govern the decay of correlations in classical chaotic systems featuring dissipation. Following this framework, a deterministic fitting method is applied to the correlation functions of numerical simulations of closed unitary quantum systems. This examination will focus on how the number of frequencies needed to reproduce correlation functions relates to other signatures of quantum chaos.

TT 99.11 Fri 12:30 HÜL/S186

Refinements of the Eigenstate Thermalization Hypothesis — •Elisa Vallini[1], Laura Foini[2], and Silvia Pappalardi[1] — [1]University of Cologne, Köln, Germany — [2]Université Paris-Saclay, France

Understanding how isolated quantum many-body systems reach thermal equilibrium is a central question in nonequilibrium physics. The Eigenstate Thermalization Hypothesis (ETH) provides a powerful framework by linking thermalization to the statistical properties of matrix elements of physical observables in the energy eigenbasis.

In this talk, I will present our recent work, in which we revisit and clarify in detail the ideas that have led to the formulation of full ETH, a generalization of the ETH ansatz that captures multi-point correlation functions. Specifically, using tools from free probability, we explore the implications of local rotational invariance, a property that emerges from the statistical invariance of observables under random basis transformations induced by small perturbations of the Hamiltonian.

This approach allows us to analytically characterize subleading corrections to matrix-element correlations, thereby refining the ETH ansatz. Finally, I will show numerical results from non-integrable Floquet systems that support our analytical predictions.