Quantum Chaos 2025 - International Conference

Honoring Felix Izrailev's 60 years of research

Book of abstracts

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Contents

Talks

Absence of localization in interacting spin chains with a discrete symmetry

Yevgeny Bar Lev
Ben-Gurion University of the Negev

In this talk, I will present a proof of delocalization in spin chains symmetric under a combination of mirror and spin-flip symmetries and with a nondegenerate spectrum. The proof applies to two prominent examples: the Stark many-body localization system (Stark-MBL) and the symmetrized many-body localization system (symmetrized–MBL). I will also provide numerical evidence of delocalization at all energy densities in these models and show that the delocalization mechanism appears robust to weak symmetry breaking.

Geometric phases old and new

Michael Berry
University of Bristol

The waves that describe systems in quantum physics can carry information about how their environment has been altered, for example by forces acting on them. This effect is the geometric phase. It occurs in the optics of polarised light, where it goes back to the 1820s; it influences wave interference. The underlying mathematics is geometric: parallel transport (explaining how falling cats turn). Associated with the geometric phase are the curvature and metric 2-forms. Incorporating the back-reaction of the geometric phase on the dynamics of the changing environment exposes an unsolved problem: how can a system be separated from a slowly-varying environment? The concept has a tangled history.

Classical and quantum chaos in many-body systems

Fausto Borgonovi
Università Cattolica

TBA

Many-Body Quantum Chaos and the Spectral Form Factor

Amos Chan
Lancaster University

The study of spectral statistics is of importance in physics due to its simplicity, universality, and utility as a diagnosis of quantum chaos and localization. Recently, as a probe of spectral statistics, the spectral form factor (SFF) has been instrumental in pinpointing novel signatures of quantum chaos in the presence of many-body interactions [1], in discovering the random matrix theory behaviour of black holes [2], and in providing insights on the existence of the many-body localization phase in the thermodynamic limit [3]. In this talk, I will provide an overview of the generic behavior of the SFF in closed [4] and open [5] strongly interacting many-body quantum chaotic systems, along with its experimental measurement in quantum simulators [6].

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Broken quantum classical correspondence in quasi-static protocols

Doron Cohen
Department of Physics, Ben-Gurion University

Quantum mechanically, a driving process is expected to be reversible in the quasistatic limit, aka adiabatic theorem. This statement stands in opposition to classical mechanics, where mix of regular and chaotic dynamics implies irreversibility. We discuss prototype protocols where this observation has a practical implications: many-body adiabatic passage along Bose-Hubbard chains [1]; and an atomtronic superfluid ring whose rotation velocity is gradually varied [2]. The conditions for breakdown of quantum-to-classical correspondence are highlighted.

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Quantum scarring in many-body quantum systems

Ceren Dag
Indiana University & Harvard University

Quantum scars, introduced within the context of single-particle billiard model in 1984, are quantum eigenstates with an enhanced probability density around an unstable periodic orbit (UPO) in a chaotic phase space. Recently, nonthermal many-body eigenstates embedded in an otherwise thermal spectrum have been identified as a many-body generalization of quantum scars. This concept, however, is not associated to a chaotic phase space, and hence the connection between the single- and many- body notions of quantum scars had remained incomplete. In this talk, I will present the first quantum many-body scars originating from UPOs of a chaotic phase space in different spin models. These states verify the eigenstate thermalization hypothesis, and we thus refer to them as thermal quantum many-body scars. While they do not preclude thermalization, their spectral structure featuring approximately equispaced towers of states yields an anomalous oscillatory dynamics preceding thermalization for wavepackets initialized on a UPO. I will highlight a particular spin-1 chain which hosts both types of scars, thermal and nonthermal where the latter is associated with stable periodic orbits. Time permitting, I will also provide evidence for the ubiquity of scarred quantum eigenstates in a generic spin-1/2 chain, and how scarring makes the system more likely to be found on an orbit it was initialized on, retaining a memory of its past.

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Spectral Properties of Relativistic Quantum Billiards versus those of Haldane Graphene Billiards

Barbara Dietz

Center for Theoretical Physics of Complex Systems, Institute for Basic Science, and Korea University of Science and Technology, Daejeon

In distinction to nonrelativistic quantum billiards (QBs), relativistic neutrino billiards (NBs), which consist of a spin-1/2 particle governed by the Weyl (Dirac) equation and confined to a bounded planar domain, do not have a well-defined classical limit. Yet, their spectral density is well approximated by a semiclassical trace formula, that is, in terms of a sum over periodic orbits of the classical dynamics associated with the QB. This led to the question to what extent the Berry-Tabor & Bohigas-Giannoni-Schmit conjectures concerning the spectral properties of typical nonrelativistic quantum systems with an integrable and chaotic classical dynamics, respectively, apply to NBs. I will present some results and then come to graphene billiards (GBs), that is finite- size honeycomb lattices. It is well known that in the region of low-energy excitations around the Dirac points, where the dispersion relation is linear, the electronic properties of graphene are described by the same relativistic Dirac equation as NBs. Yet, GBs exhibit eigenstate properties of typical nonrelativistic QBs. I will demonstrate that, on the contrary, they comply with those of NBs for GBs subject to the Haldane-model on-site potential and next-nearest-neighbor tunneling at critical points.

Thermalization Universality Classes for Weakly Nonintegrable Many-Body Dynamics

Sergej Flach
Institute for Basic Science

We observe different universality classes in the slowing down of thermalization of many-body dy namical systems upon approaching integrable limits. Two fundamentally distinct long-range (LR) and short-range classes (SR) are distinguished by the nonintegrable perturbation network spanned amongst the (set of countable) actions of the corresponding integrable limit. Weak two-body interactions (nonlinearities) induce LR networks in translationally invariant lattices. Weak lattice coupling (hopping) instead induce SR networks [1,2,3]. For classical systems we study the scaling properties of the full Lyapunov spectrum [4,5,6]. The LR class results in a single parameter scaling of the Lyapunov spectrum, with the inverse largest Lyapunov exponent being the only diverging time control parameter and the rescaled spectrum approaching an analytical function [4,6]. The SR class results in a dramatic slowing down of thermalization and a rescaled Lyapunov spectrum approaching a non-analytic function. An additional diverging length scale controls the exponential suppression of all Lyapunov exponents relative to the largest one [4,6]. Disorder induces transitions from LR to SR classes [7]. For quantum spin chains we compute ergodization time scales within the framework of the Eigenstate Thermalization Hypothesis and the Lyapunov time from operator growth methods using Krylov Complexity [8]. The comparison of both time scales confirms the existence of the above universality classes for quantum many body dynamics as well.

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Kac-Rice approach to non-Hermitian random matrices

Yan Fyodorov
King's College London

Non-Hermitian random matrices attracted considerable interest in recent years as a tool to characterize Quantum Chaos in dissipative systems. Still, available tools to address their properties are quite limited. I will describe an approach based on Kac-Rice formula which provides access not only to eigenvalues but also to nontrivial eigenvectors of non-Hermitian random matrices. To illustrate utility of this approach I will consider two cases: first of matrices interpolating between complex Ginibre and real Ginibre ensembles and second of complex symmetric matrices. In particular, the approach allows to reveal a new scaling regime of "weak non-reality".

Localization of light in Lévy disordered photonic lattices: effects of inhomogeneous disorder on Anderson localization

Victor Gopar
Universidad de Zaragoza

Localization of coherent propagating waves has been extensively studied in homogeneous random media. However, significantly less attention has been given to wave localization in inhomogeneous systems, where the standard picture of Anderson localization does not apply. By fabricating photonic lattices with inhomogeneous disorder modeled by heavy-tailed distributions, namely Lévy α-stable distributions, and measuring the output light intensity profiles, we show that the spatial localization of light is asymmetric with respect to the excitation site and is described by a stretched exponential function. The results contrast with the well-known exponential localization in Anderson localization phenomena.

Power-law banded random matrices for quantum many-body phyiscs

Masud Haque
Tech. Univ. Dresden, Germany

I will describe our explorations of interpreting the power-law banded random matrix ensemble as Hamiltonians of one-dimensional quantum many-body systems.

Loss of integrability in a system with two-photon interactions

Jorge G. Hirsch
Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México

Light-matter systems that exhibit two-photon interactions have emerged as powerful platforms for exploring quantum applications. In this work, we focus on the two-photon Dicke model, a system of significant experimental relevance that displays spectral collapse and undergoes a phase transition from a normal to a superradiant phase. We analyze the normal phase, where a classical limit with two degrees of freedom can be derived using a mean-field approximation. Our study presents a detailed investigation of the loss of integrability in the two-photon Dicke model, employing both quantum and classical diagnostics. These results allow us to explore various dynamical features of the system, including the onset of chaos and the existence of mixed phase-space behavior

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The Correspondence Principle, Ergodicity, and Finite-Time Dynamics

Liang Huang
Lanzhou University

The quantum-classical correspondence stands out as one of the most intriguing challenges in the realm of quantum mechanics. Within the context of quantum chaos, the conventional approach, which relies on spectral statistics to infer distinct classical dynamical properties, fails in typical scenarios, such as slow relaxation processes, dynamical localization or other deviations from ergodicity. To address this difficulty, we propose a novel approach the essence of which lies in associating a quantum energy shell with classical finite-time trajectories. Our results extend the knowledge of quantum-classical correspondence, they offer explanations for previously conflicting findings, and they also bear significance for applications in quantum metrology, sensing, and computation when the determination of the ergodicity degree of the quantum states is in need.

Chaos and onset of thermalization in closed systems of strongly interacting particles

F. M. Izrailev
Instituto de Física, Benemérita Universidad Autónoma de Puebla

We develop the semi-analytical approach to the problem of thermalization of a finite number of Bose-particles in the absence of a heat bath. In contrast with many studies of thermalization defined in terms of the relaxation of various global and local observables, we focus on the emergence of Bose-Einstein (BE) distribution of single-particle occupation numbers in dependence of the number of particles and strength of inter-particle interac- tion. In our approach we assume that the total Hamiltonian H can be presented as the sum of the mean field H_0 describing non-interacting particles, and the two-body random interaction V . In the study we consider N identical bosons occupying M single-particle levels specified by random unperturbed single-particle energies. We show how strong in- teraction between particles results in a chaotic structure of eigenstates considered in the unperturbed basis of non-interacting part of the Hamiltonian. When an eigenstate can be treated as strongly chaotic, we demonstrate that the BE distribution emerges in the cor- respondence with our analytical estimates. This allows one to introduce the temperature for a single chaotic eigenstate. The numerical data manifest excellent correspondence of the occuation number distiribution to the modified BE distribution in view of a strong inter-particle interaction. We also show how the BE distribution emerges in time in the process of the relaxation of the wave packet in the Hilbert space, in the quench dynamics approach.

Harnessing multiple-scattering electromagnetic environments for wave-control via in-situ adjoint optimization

Tsampikos Kottos
Wesleyan University

We develop an in-situ time- and energy-efficient adjoint optimization (AO) methodology for the manipulation of wave scattering in multiple scattering systems and demonstrate wave-driven functionalities like targeted channel emission, coherent perfect absorption and camouflage. Our paradigm leverages these highly multi-path complex environments which dramatically amplify small local system AO-informed variations.

Viscous phononic metamaterials

Arkadii Krokhin
University of North Texas

A theory of homogenization of phononic crystals with viscous fluid background and solid elastic scatterers is developed. The effective speed of sound and effective viscosity are calculated analytically in the low-frequency limit. It is shown that a periodic dissipative elastic structure behaves as anisotropic metafluid. A concept of viscous supercrystal is introduced and experimentally verified.

Dwell time in many-body chaotic systems

Caio Lewenkopf
Universidade Federal do Rio de Janeiro

We investigate the dependence of scattering delay time on quantum statistics in many-body systems. Is the scattering delay time longer for fermions or bosons in a many-body system? Does chaos play a role? These are the central questions we discuss in this talk. Extending the standard Wigner-Smith theory for single-particle scattering, we develop a formal theory for many-body dwell times. Analogous to its single-particle counterpart, this many-body delay time is intimately related to the many-body density of states. We analyze the properties of the many-body density of states for both fermionic and bosonic systems, spanning integrable and chaotic regimes. Based on this, we present novel results for the many-body dwell times, elucidating their dependence on quantum statistics and system dimensionality. Our findings offer a deeper understanding of quantum transport phenomena in interacting systems.

Extreme spectral properties of random graphs

Claudia Teresa Martínez-Martínez
Universidad Autónoma de Guerrero

In this work, we analyze the extreme spectral properties of random networks with random weights and self-connections, specifically in two models: Erdős-Rényi (ER) graphs and random geometric networks (RGG). The spectral density is studied as a function of the average degree of connectivity. We characterize the behavior of the largest and second-largest eigenvalues by deriving an expression for the average value of the largest eigenvalue as a function of the average degree. Unlike binary graphs, we find that the extremal spectral properties of weighted random graphs are not far from the bulk of the spectrum. For sufficiently high connectivity, the distribution of these eigenvalues follows the Tracy-Widom type 1 distribution. Additionally, we analyze the distance and ratio between the two largest eigenvalues, showing that these quantities, like the spectral bulk, capture important information about the network's connectivity regime and are fixed by fixing the average degree. This indicates that it is possible to characterize graphs by studying only the extreme spectral properties. Finally, the inverse participation ratio (IPR) is studied, observing that the IPR distinguishes between extreme and center eigenvalues, demonstrating its sensitivity to local connectivity.

Electronic quantum transport in ballistic microstructures with point symmetries

Moisés Martínez-Mares
Departamento de Física, Universidad Autónoma Metropolitana-Iztapalapa

Statistical fluctuations of dimensionless conductance of ballistic cavities with a particular point symmetry are analyzed. It is assumed that the scattering matrix of the system is diagonalizable by a rotation by an arbitrary angle in 2×2 blocks of independent scattering matrices. Assuming that these independent scattering matrices are chosen from one of the circular ensembles, or from the Poisson kernel, the scattering matrix of the system may describe the scattering through chaotic cavities in the absence, or presence, of direct processes, respectively. In the presence of direct processes Ihe statistical distribution of the dimensionless conductance is obtained in the single channel case. In the absence of direct processes a statement is proposed for the two channels case , which is verified by random matrix theory simulations, and the first two moments for an arbitrary number of channels are calculated analytically.

Emulating tight-binding models with coupled-resonator phononic systems

Rafael Méndez
Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México

Coupled-resonator phononic systems, recently introduced by our group, are vibrational systems governed by a tight-binding model analogous to those used in condensed matter physics. In this talk, we present an overview of these systems, focusing on their capability to emulate various molecular structures. We demonstrate the emulation of linear and two-dimensional molecules, ranging from a few atoms to several dozen, incorporating first-, second-, and third-neighbor hoppings [1–3]. We illustrate the results for coupled-resonator phononic benzene and borazine molecules and their agreement with the Hückel Model. The band structure of a trans-polyaminoborane chain with both first- and second-neighbor interactions agrees with the results of the kappa-deformed Dirac equation. A cis-polyacetylene with first- and third-nearest-neighbor hoppings shows a double topological phase transition.

Topological phases in spinor Bose-Einstein condensates

Rosario Paredes Gutiérrez Paredes
Instituto de Física UNAM

Inter-particle interactions and spin-orbit coupling are the essential ingredients behind the emergence of Skyrmions in spinor condensates confined in the two-dimensional space. Topological defects appearing in the spin texture of condensates confined in square and hexagonal lattices are classified in terms of both, the topological charge and the index. A plethora of phases observed are the result of numerical experiments within the mean-field Gross-Pitaevskii scheme.

The global out-of-time-order correlators as a signature of the scrambling dynamics of local information in homogeneous many-body systems.

Horacio Miguel Pastawski
Instituto de Física Enrique Gaviola-Universidad Nacional de Córdoba- CONICET

Characterizing how quantum information scrambles across a system is a complex challenge, much like trying to separate the ingredients of a smoothie after they've been blended and shaken. To address this issue, physicists developed a range of techniques known as Loschmidt Echoes (LE) and Out-of-Time-Order Correlators (OTOCs). Although these methods emerged independently in different fields, they share similarities and are often equivalent, as both involve a "backward evolution" that simulates time reversal after a disturbance. This process helps to untangle the mixed information while using perturbations to mark how far each part has scrambled and spread.

In the realm of Nuclear Magnetic Resonance (NMR), LEs and OTOCs have been used for over half a century to measure correlations among spins, with applications across various disciplines. However, a significant challenge arises because NMR experiments typically rely on global measurements—considering all spins together—rather than focusing on local ones, which is the approach taken in most theoretical and numerical studies. Most experimental implementations of OTOCs to probe information scrambling rely on indirect measurements based on global observables, using techniques such as Loschmidt echoes and multiple quantum coherences, via time-reversal evolutions [1]. In this article, we establish a direct connection between OTOCs with global and local observables in the context of NMR experiments. Our basic hint is that the global echo arises from averaging many local echoes whose strengths depend on the sudden "shake" perturbation after the "blending" dynamics, as those shown in the figure. Importantly, the primary contribution to the global echo comes from local excitations returning to their original sites, while contributions from neighboring spins tend to cancel out due to the intricate interferences developed during evolution.

In NMR, the observable is the total spin magnetization of the system. We conduct a numerical analysis to quantify the differences in the evolution of both magnitudes, evaluating the excitation dynamics in spin ring systems with 8 to 16 spins, using a many-body Hamiltonian and long-range interactions. Our analysis decomposes the global echo into a sum of local echoes and cross-contributions, leading to local and global OTOCs [2]. The results indicate that, after an initial transient period, local OTOCs determine the global ones. We observe that the difference between the average of local OTOCs and the global one, as well as their fluctuations, becomes negligible as the system size increases. Thus, our study demonstrates that

in large and complex systems, after a transient initial evolution, results obtained from global measurements are equivalent to those from local measurements. This insight strengthens and validates the interpretation of recent NMR experiments on fundamental issues such as localization of excitation from multispin interactions and the emergence of intrinsic irreversibility in large quantum systems.
In summary, for large homogeneous systems, global and local OTOCs become equivalent. This behavior aligns with that observed in highly interacting or chaotic systems in several experiments.

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Survival probability in random network models

Kevin Peralta Martinez
IFUAP - BUAP

We study the survival probability of an initial state of the ER network model represented by the orthogonal randomly weighted adjacency matrix AO in the context of its full random matrix ensemble (GOE) formulation. We introduce the construction of the random network model, and describe the behaviour of the survival probability of the ER model in terms of its inherent parameters. We show that the relative depth of the correlation hole of the survival probability can be scaled with the average degree $\langle k \rangle$, and that the survival probability can be well characterized at different time scales by fixing the average degree $\langle k \rangle$ with varying network sizes n. Furthermore, we show that the generalized fractal dimensions of the inverse participation ratio describe the decay of the time-averaged survival probability.

Confined and deconfined chaos in Hamiltonian systems

Anatoli Polkovnikov
Boston University

In this talk I will first discuss how one can define chaos both in quantum and classical systems using quantum geometric tensor or equivalently fidelity. In this way chaos can be understood either through irregular dynamics of observables or through instabilities of time averaged probability distributions/quantum states to infinitesimal perturbations. Then I will focus on emergence of chaos/ergodicity/mixing from slightly perturbed integrable models. I will argue there are at least three distinct universality classes : critical, confined , and deconfined. Critical chaos emerges in, for example, disordered models close to localization transition or in low dimensional classical systems with mixed phase space. It is characterized by slow power-law relaxation. Confined chaos is the most common scenario occurring in local interacting models. It is characterized by fast relaxation of angle variables and much slower relaxation of actions, which can be described perturbatively by standard kinetic approaches. Finally, deconfined chaos can occur in perturbed superintegrable models with highly inhomogeneous phase space. It is characterized by the fastest possible non-perturbative decay rate, which scales as the absolute value of the integrability breaking coupling. In this scenario there is no separation between relaxation of action and angle variables. An example of a system where deconfined chaos is realized is the central spin XX-model at zero energy. Other likely candidate for the deconfined chaos is the SYK model.

Nonequilibrium Dynamics in Strongly Disordered Two-Dimensional Electron Systems

Dragana Popovic
National High Magnetic Field Laboratory, Florida State University

This talk will describe experimental studies of nonequilibrium dynamics in strongly disordered two-dimensional electron systems (2DESs) in the vicinity of a quantum metal-insulator transition. Measurements of the evolution of conductivity with time are performed using different experimental procedures, such as quantum quench, thermal quench, and waiting-time protocols. The results obtained on 2DESs with a different range of the Coulomb interaction will be discussed and compared.

From integrability to chaos in open quantum systems

Molina Rafael
Instituto de Estructura de la Materia (CSIC)

The dynamics of open quantum systems can be described by a Liouvillian, which in the Markovian approximation fulfills the Lindblad master equation. We present a family of integrable many-body Liouvillians based on Richardson-Gaudin models with a complex structure of the jump operators. Making use of this new region of integrability, we study the transition to chaos in terms of a two-parameter Liouvillian. The transition is characterized by the spectral statistics of the complex eigenvalues of the Liouvillian operators using the nearest neighbor spacing distribution and by the ratios between eigenvalue distances. We also study the statistics of the dissipative gap that controls long time evolution and the decay into the steady state of the system in the transition between integrability and chaos.

Onset of Quantum Chaos and Ergoditicy in Spin Systems with Highly Degenerate Hilbert Spaces

Marcos Rigol
Penn State

We show that in systems with highly degenerate energy spectra, such as the 2D transverse-field Ising model (2DTFIM) in the strong-field limit, quantum chaos can emerge in finite systems for arbitrary small perturbations. In this regime, the presence of extensive quasi-conserved quantities can prevent finite systems from becoming ergodic. We study the ensuing transition to ergodicity in a family of models that includes the 2DTFIM, in which the onset of ergodic behavior exhibits universality and occurs for perturbation strengths that decrease polynomially with increasing system size. We discuss the behaviors of quantum chaos indicators, such as level spacing statistics and bipartite entanglement, and of the fidelity susceptibilities and spectral functions across the transitions.

Probing chaos and ergodicity in synthetic quantum matter

Joaquin Rodriguez Nieva
Texas A&M University

A central challenge in the theory of statistical mechanics is understanding how chaos and ergodicity emerge from isolated many-body quantum evolution. The widely-accepted definition of quantum chaos is rooted in random matrix theory (RMT), which captures coarse-grained features of typical quantum states—such as level-spacing repulsion and volume-law entanglement entropy. In this talk, I will show that far richer universal structures emerge when we go beyond RMT and study fine-grained correlations—specifically, higher statistical moments—of quantum state ensembles through the lens of modern observables accessible in synthetic quantum matter. These fine-grained correlations are not only of theoretical interest but also increasingly relevant for quantum technologies, including the certification of quantum randomness generation and the benchmarking of quantum devices. I will focus on two key classes of quantum state ensembles—the eigenstate ensemble [1–3] and the temporal ensemble [4]—and show that while both display RMT-like behavior at the average, coarse-grained level, they reveal richer statistical and dynamical phenomena at higher moments, including maximally chaotic regimes and universal corrections to entanglement entropy statistics.

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Timescales for thermalization and many-body quantum chaos

Lea Santos
University of Connecticut

The timescale for isolated many-body quantum systems to reach thermal equilibrium after a dynamical quench remains an important open question. We examine how the equilibration process depends on the models, observables, energy of the initial state, and system size, revealing distinct dynamical behaviors across different timescales. Special attention is given to the dynamical manifestations of many-body quantum chaos and methods for detecting them in experimental setups, such as cold atoms, ion traps, and NMR systems. We show that coupling the system to a dephasing environment can reduce dynamical fluctuations that might otherwise obscure these manifestations.

Controlling the Electronic Transport in Two-Dimensional Quantum Materials

Thomas Stegmann
Universidad Nacional Autónoma de México

In this talk, we explore various strategies for manipulating and controlling the electronic transport in two-dimensional quantum materials, with an emphasis on graphene. We show that Kekulé-type distortions in graphene allow the current to be guided along well-defined paths. By considering a graphene bilayer, we demonstrate that it is possible to deflect the current through a relative twist between the layers. Additionally, we discuss the emergence of anomalous edge states in this system, which open up new possibilities for transport control. Finally, we show that these strategies are not limited to graphene, but can also be extended to other two-dimensional materials, such as phosphorene, paving the way for new approaches in the design of quantum electronic devices.

Spin resonance without a spin: A microwave analog

Hans-Jürgen Stöckmann
Department of Physics, University of Marburg

An analog of nuclear magnetic resonance is realized in a microwave network with symplectic symmetry. The network consists of two identical sub-graphs coupled by a pair of bonds with a length difference corresponding to a phase difference of π for the waves traveling through the bonds. As a consequence all eigenvalues appear as Kramers doublets. Detuning the length difference from the π condition Kramers degeneracy is lifted, which may be interpreted as a Zeeman splitting of a spin $1/2$ in a magnetic field. The lengths of another pair of bonds are modulated periodically with frequencies of some 10 MHz by means of diodes, thus emulating a magnetic radiofrequency field. Features well-known from NMR such as the transition from the laboratory to the rotating frame, as well as Lorentzian shaped resonance curves can thus be realized.

Localisation and transport in 2D and 3D random media with spherical symmetry

Luca Tessieri
Facultad de Ciencias Físico-Matemáticas - Universidad Michoacana de San Nicolás de Hidalgo

We consider Anderson localisation in specific bi- and tri-dimensional random models with radial/spherical symmetry. We show how the spherical symmetry makes possible to reduce these models to one-dimensional problems; more specifically, we discuss how the random potential produces localisation of the eigenstates along the radial directions and under what conditions the localisation length of the 2D and 3D models coincides with that of their 1D counterparts. We also show how disorder correlations can be used to modulate the transport properties of finite-size systems.

Controlling Many-Body Quantum Chaos: Optimal Coherent Targeting

Steven Tomsovic
Washington State University

The control and stabilization of many-body quantum systems whose classical counterparts exhibit highly chaotic motion is a challenging problem. The presence of many-body quantum chaotic dynamics is often conceptualized as the ultimate enemy of quantum device control as it leads rapidly to thermalization, and is certainly a fundamental hindrance to controlling quantum computation. However, what if chaos could be harnessed instead as a resource for quantum control just as has been shown for classical systems?
One of the principal goals of controlling classically chaotic dynamical systems is known as targeting, which is the very weakly perturbative process of using the system's extreme sensitivity to initial conditions in order to arrive at a predetermined target state. It relies on a kind of "inverse butterfly effect": fast exponential convergence. In this talk we develop a many-body quantum control technique inspired by classical targeting. Starting from an initial quantum state in a quantum chaotic system: "how can one transfer the chaotic many-body system to a predetermined remote target state most efficiently?"

Reducing dynamical fluctuations and enforcing self-averaging by opening many-body quantum systems

Isaias Vallejo
University of Connecticut

This talk is based on our paper [1], which presents beneficial influences of a dephasing environment on many-body quantum systems out of equilibrium. Specifically, interactions with the environment can be used to mitigate dynamical fluctuations and to ensure self-averaging. Enforcing self-averaging is important, because it implies that the number of samples used in experiments and in numerical analysis can be decreased as the system size increases. We consider the survival probability (i.e., spectral form factor with a filter) evolving under different kinds of random matrices and under a spin-1/2 model with weak and strong onsite disorder. In isolated many-body quantum systems, the survival probability is non-self-averaging at any timescale, that is, the relative variance of its fluctuations does not decrease as the system size grows. By opening the system, we find that the fluctuations are always reduced, and self-averaging is ensured away from critical points.

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Solid-state phenomena in photonic lattices

Rodrigo Vicencio
Universidad de Chile

In this talk, I will review recent experimental results on transport and localization phenomena observed in one and two-dimensional lattices. I will start by describing the analogy in between an atom and a waveguide, which allows us to experimentally simulate tight-binding-like physics in photonic systems. I will describe how diamond [1] and graphene [2] 1D lattices, in the presence of effective magnetic fields, allow the observation of Aharonov-Bohm caging and topologically compact edge states. Dipolar interactions could produce a zero coupling at the "invisibility angle", independently of the distance among the dipolar states. We observe the invisibility angle for photonic couplers fabricated at different orientation angles and probe its impact on 2D lattices, by showing a localization transition in photonic Graphene for bulk and corner excitations [3]. I will also describe very recent results on multi-orbital Fano resonances, anomalous Levy transport, radiation phenomena in structured reservoirs, and a photonic implementation of strong long-range coupling.

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Fading ergodicity

Lev Vidmar
Jožef Stefan Institute and University of Ljubljana

Recent decades of research contributed significantly to our understanding how an interacting quantum system, evolving in isolation from environment, approaches a thermal equilibrium. The process in which the expectation values of observables after a long time approach predictions from the thermal Gibbs ensembles is called thermalization, and the state of the system is referred to as being ergodic. The mechanism of thermalization is today understood via the eigenstate thermalization hypothesis, which states that all eigenstates of a Hamiltonian are already thermal. I will also discuss counterexamples to thermalization. In particular, I will comment on our recent proposal of the regime of "fading ergodicity", which acts as a precursor of the ergodicity breaking phase transition.

Dissipation and the correspondence principle

David Benjamín Villaseñor Pérez
CAMTP, University of Maribor, Slovenia

We analyze periodically kicked systems with damping, which has led to the current definition of dissipative quantum chaos based on the universality of spectral correlations. We provide enough numerical evidence about the breaking of the correspondence principle when we examine sufficiently broad parameter ranges of these periodically kicked systems. These results indicate the need for a new definition of dissipative quantum chaos.

Eigenvalue and eigenvector structure in many-body interacting quantum systems

Manan Vyas
Instituto de Ciencias Físicas-UNAM

We present results for eigenvalue and eigenvector structure in many-body interacting sermonic and boson systems derived using embedded random matrix ensembles and q-normal polynomials.

Characterizing the mixed eigenstates in kicked top model through the out-of-time-order correlator

Qian Wang
Center for applied mathematics and theoretical physics/Zhejiang Normal University

Generic systems are associated with a mixed classical phase space. The question of the properties of the eigenstates for these systems remains less known, although it plays a key role for understanding several important quantum phenomena such as thermalization, scarring, tunneling, and (de-)localization. In this work, by employing the kicked top model, we perform a detailed investigation of the dynamical signatures of the mixed eigenstates via the out-of-time-order correlator (OTOC). We show how the types of the eigenstates get reflected in the short- and long-time behaviors of the OTOC and conjecture that the dynamics of the OTOC can be used as an indicator of the mixed eigenstates. Our findings further confirm the usefulness of the OTOC for studying quantum complex systems and also provide more insights into the characters the mixed eigenstates.

Relativistic quantum chaotic ratchet

Hong-Ya Xu
Lanzhou University

Ratchet allows directed motion without net forces and has found important applications. We go beyond existing paradigms to explore the ratchet effect in the relativistic quantum realm and uncover a novel quantum chaotic ratchet. It is induced by the intrinsic emergence of non-uniform relativistic chaotic diffusion, and disappears in the non-relativistic limit. The local diffusion rate is derived as a function of effective parameter rescaled by the Lorentz factor that inherently generates the non-uniform diffusion and thus directed transport. Numerical verification is given using a time-periodically kicked Dirac system with classically chaotic dynamics.

Generalized survival probability

David Abraham Zarate Herrada
IFUAP-BUAP

The survival probability measures the probability that a non-equilibrium system is in some initial state at a given time. Motivated by the generalized entropies used to analyze non-ergodic states, we introduce a generalized version of the survival probability (SPq(t)) as well as a generalized local density of states (LDOSq). Using the one-dimensional spin-1/2 model with disorder, a typical model in the study of many-body localization, we compare the results for the LDOSq and the SPq(t) in the chaotic regime and far from it. We also compare results for the spin model with random matrices from the Gaussian orthogonal ensemble (GOE). We explore the behavior of the generalized quantities and investigate specific characteristics of these such as the power-law decay exponent of SPq(t) and the standard deviation of LDOSq. In the latter case, we propose an analytical expression for the entire evolution of the generalized survival probability for the case of GOE matrices.

Ruelle-Pollicott spectra and integrability of all U(1) circuits

Marko Znidaric
University of Ljubljana

I will present results on a momentum-resolved truncated propagator and its use in identifying integrable circuits, for instance, finding that homogeneous circuits with an arbitrary U(1)-conserving gate are all integrable. They harbor interesting inhomogeneous SU(2) as well as quantum group symmetries important for transport, and teach us that in the XXZ-type models isotropy and criticality are in general distinct notions. What matters is the local SU(2) criticality and not the isotropy.

Posters

Spectral Form Factor for β-Hermite Ensembles and its Relationship to one Dimensional Spin 1/2 Chaotic Models

Raul Arotaipe Ala

Institute of Physics "Ing. Luis Rivera Terrazas"

The study of chaos indicators in many-body quantum systems remains an open problem. Here, we present two models, the first is the so-called β-Hermite model of the RMT formed by tridiagonal random matrices with real elements and whose spectral properties are analogous to classical ensembles (GOE, GUE, GSE) of the RMT for the real parameter $\beta = 1, 2, 4$, respectively. The second is a 1/2 spin model, unique in that it presents the three symmetries of the classical RMT ensembles with the objective of numerically studying their static properties and in the time domain. For both models we analyze the density of states (DoS), the repulsion (P (r)) and the variance of the number of energy eigenvalues (LN V) of the energy spectrum. In particular, emphasis is placed on the spectral form factor (SF F) which has been shown to be a highly relevant tool for diagnosing signals of the chaotic nature of a quantum system. The analyzes of the quantum chaos indicators for the 1/2 spin model are compared with those called β-Hermite ensembles.

The results show that the DoS of both models differ, since it is not a universal property. On the other hand, the repulsion of consecutive energy eigenvalues of both models is similar and captures a universal characteristic of chaotic quantum systems depending only on the class of universality. It's found that the LNV in the case of the spin model 1/2 it deviates from the behavior predicted by the RMT at a point associated with the Thouless energy for each symmetry of the system. Furthermore, it is found that the Thouless energy increases with the size of the system. While for the β-Hermite assemblies the LNV does not deviate from the analytical curves, showing a good correspondence for each β. In the case of SF F we find that it is a tool with potential, since it reflects the static properties in the time domain. In both models there are interesting and typical zones of chaotic quantum systems for each class of universality. The initial zone is connected to peculiarities such as the type of interaction between particles in the model, so it doesn't have universal behavior.

The first universal zone that appears in the SF F is the dip associated with the Thouless time in connection with the Thouless energy of the LNV . The second zone is the ramp, a universal characteristic typically connected to the repulsion between consecutive energy eigenvalues for both models, i.e. P (r). The dip and ramp form the correlation hole and it is deeper when β increases in both models. The third zone is saturation where the system reaches the maximum of the ramp and tends to a constant value, this occurs for both models.

Universal transport and time delays in tight-binding random graphs

Kevin Blass Hidalgo Castro

Within the scattering matrix approach to electronic transport, we study the scattering, transport, and internal dynamic properties of tight-binding random graphs focusing on Random Geometric Graphs (RGGs) and bipartite RGGs. Our analysis covers key quantities such as the scattering matrix elements, total and channel-to-channel transmission distribution, Wigner delay times and resonance widths. By evaluating these systems under both multi- and single channel lead configurations, we observe a smooth crossover from insulating to metallic behavior as the average node degree increases. This transition, as well as the statistical properties of Wigner delay times and resonance widths, exhibit universal behavior when scaled by a parameter $\xi = \langle k||N\rangle^{-\alpha}$, where α depends on the graph model. In the high-connectivity regime and under perfect coupling conditions, the scattering characteristics of these graphs align with predictions from random matrix theory, except in certain bipartite graph configurations. These findings underscore a universal behavior across graph models and suggest experimental relevance in photonic systems emulating complex networks.

Disordering a permutation symmetric system: revivals, thermalisation and chaos

Manju C C
Indian Institute of Technology Palakkad

This study explores the effects of introducing a symmetry breaking disorder on the dynamics of a system invariant under particle permutation. The disorder forces quantum states, confined to the N+1 dimensional completely symmetric space to penetrate the exponentially large 2^N dimensional Hilbert space of N particles. In particular, we focus on the quantum kicked top as a Floquet system of N qubits, and use linear entropy, measuring single qubit entanglement, to investigate the changes in the time scales and values of saturation when disorder is introduced. In the near-integrable regime of the kicked top, we study the robustness of quantum revivals to disorder. We also find that a classical calculation yields the quantum single qubit entanglement to remarkable accuracy in the disorder free limit. The disorder, on the other hand, is modeled in the form of noise which again fits well with the numerical calculations. We measure the extent to which the dynamics is retained within the symmetric subspace and its spreading to the full Hilbert space using different quantities. We show that increasing disorder drives the system to a chaotic phase in full Hilbert space, as also supported by the spectral statistics.We find that there is robustness to disorder in the system, and this is a function of how chaotic the kicked top is.

Entanglement and Spectral Statistics in Perturbed Quantum Systems

Francisco Correa Alvarado
IFUAP - BUAP

Using concepts and tools from quantum chaos, random matrix theory, and quantum information theory, we study the effects of a local perturbation on the properties of a one-dimensional many-body quantum system. In particular, we analyze how the energy level statistics, energy eigenstate structure, and quantum entanglement in the Ising model of a one-dimensional string with a transverse field depend on the magnitude of a local perturbation applied halfway along the string.

Chaos and regularity in a soft anisotropic squircle billiard

Adán González Andrade
Universidad Autónoma Metropolitana - Iztapalapa

Billiards are a paradigmatic model in the study of both classical and quantum chaos [1], as their dynamics are entirely determined by geometry [2]. This work focuses on the classical study of billiards with walls modeled by a smooth potential, instead of the conventional infinite potential well (hard walls). It has been observed that introducing smoothness into the walls of a billiard has a stabilizing effect on the dynamics [3, 4]. Soft billiards have been experimentally implemented, for example, using cold atoms [5] and exciton-polariton systems in semiconductor microcavities [6]. We present the study of a soft billiard with a squircle shape—a geometric figure combining the angularity of a square with the smooth curves of a circle—in its anisotropic case. We characterize the transition to chaos and the stabilization of the dynamics by revealing the nonlinearity of the parameters (squareness, ellipticity, and hardness) through the computation of Poincaré maps and Lyapunov exponents across the parameter space. Furthermore, we offer perspectives on smooth billiards as platforms for studying quantum chaos and scarring [7].

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Non-Hermitian diluted banded random matrices: Scaling of eigenfunction and spectral properties

Marisol Hernandez Sanchez
Benemerita Universidad Autonoma de Puebla

Here we introduce the non-Hermitian diluted banded random matrix (nHdBRM) ensemble as the set of $N \times N$ real non-symmetric matrices whose entries are independent Gaussian random variables with zero mean and variance one if $|i - j| < b$ and zero otherwise, moreover off-diagonal matrix elements within the bandwidth b are randomly set to zero such that the sparsity α is defined as the fraction of the $N(b - 1)/2$ independent non-vanishing off-diagonal matrix elements. By means of

a detailed numerical study we demonstrate that the and spectral properties of the nHdBRM ensemble scale with the parameter $x = \gamma[(b\alpha)^2/N]^\delta$, where $\delta \sim 1$. Moreover, the normalized localization length β of the eigenfunctions follows a simple scaling law: $\beta = x/(1+x)$.

Time series approach to characterize the phase transition in the 1D Aubry-André model

Miriam Jiménez Valdez
IFUAP

We characterize the metal-insulator transition in the one-dimensional Aubry André model (with and without interactions) by using the squared module of the Fourier transform of spacings between adjacent energy levels, that is through so-called power spectrum. We also study some properties of the system in the chaotic regime and localized regime.

Mushroom billiards II: Structure of quantum eigenstates and their localization properties

Matic Orel Orel
CAMTP - Center for Applied Mathematics and Theoretical Physics

This paper continues our previous work [9], which presented the first analysis of the gap ratio spectral statistic in the mushroom billiard—a mixed-type, non-KAM system [5]. Here, we focus on the localization properties of its eigenfunctions by studying the distributions of localization entropies derived from their Poincaré-Husimi (PH) functions, as well as their inverse participation ratios (IPR). For the entropy distributions, we find that at large stem widths, they are well described by a beta distribution fit. Additionally, we analyze the decay behavior of eigenstates whose overlap indices [8] lie strictly within the interval (-1,1) and show that this decay follows a power-law. These findings support the principle of uniform semiclassical condensation (PUSC) [7], implying that in the semiclassical limit, the fraction of mixed states vanishes, leaving only regular or chaotic eigenstates.

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Study of the spectral properties of random matrix ensembles with local and global constraints: The Diluted Case

Alfredo Orozco Viveros
Instituto de Física "Ing. Luis Rivera Terrazas" (IFUAP)

In this project we study the spectral properties of diluted random matrix ensembles restricted to global and local constraints. First, several key quantities related to the eigenvalues and eigenvectors of these ensembles are computed and analyzed. Once the basic calculations are understood, the study explores how these properties change as the matrices are diluted. Finally, the possible existence of a scaling parameter will be explored; one that, as a combination of the system's parameters, allows the characterization of specific properties of the ensemble.

On the hyper-parameters that lead to Anomalous Localization on 1D inhomogeneous random madia

Alejandro Ramírez Yañez
Universidad de Guadalajara

Localization of coherent propagating waves has been extensively studied during the years, assuming homogeneous random media. However, there has been considerably less attention on wave localization in inhomogeneous systems, where the standard picture of Anderson localization does not apply. Constructing lattices with inhomogeneous disorder, modeled by heavy-tailed alpha-stable distributions, allow us to demonstrate that the spatial localization of waves is described by a stretched exponential function, with a stretching parameter alpha, and an asymmetric localized

profile with respect to the excitation site. However, the hyper-parameters used to construct those latices allow us to also tune the kind of localization we observed. This work will focus on the details of system construction.

Theory of Resonance Assisted Tunneling in Floquet spin-J systems.

Jesus Alfonso Segura Landa
Instituto de Ciencias Nucleares

In this work, we investigate resonance-assisted tunneling (RAT) in a periodically driven many-body quantum system. We identify that the onset of RAT is mediated by nonlinear resonances in the semiclassical phase space. We show that the regime of validity of the RAT framework is bounded by the critical strength of the kicking perturbation at which a particular eigenstate becomes Einstein–Brillouin–Keller (EBK) quantizable within a resonance island. We finally show the scaling of such critical strength with respect to the effective Planck constant.

Adiabatic gauge potential approach to characterize the onset of chaos in quantum many-body systems with interactions

Julio Cesar Texca Garcia
IFUAP-BUAP

In this work, we investigate the adiabatic gauge potential (AGP) as a diagnostic tool for quantum many-body chaos. To this end, we study two interacting systems: the one-dimensional Heisenberg spin-1/2 chain with an on-site defect that breaks integrability and additional edge impurities, and the interacting Aubry-André model with nearest-neighbor interactions. In the first part of the study, we analyze both models using standard techniques from random matrix theory, focusing on spectral properties and energy eigenstate statistics. We then explore the onset of quantum chaos in these systems through the behavior of the AGP, highlighting its effectiveness as a probe of non-integrable dynamics.

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