Dissipative Quantum Chaos - DiQuaC 2026

14th – 15th September 2026, Spazio SOI - Via Tommaso Gar, 16/2, Trento

Conference Abstract Booklet

Monday, September 14th

Spectral statistics in dissipative quantum chaos: from random matrices to quantum computers

Speaker: Lucas Sá

More than four decades of research on chaos in isolated quantum systems have led to the identification of universal signatures, such as level repulsion, that serve as cornerstones in our understanding of complex quantum dynamics. The emerging field of dissipative quantum chaos explores how these properties manifest in open quantum systems, where interactions with the environment play an essential role. Here, I will discuss the theoretical proposal, numerical observation, and first experimental detection of dissipative quantum chaos and integrability using complex spacing ratios (CSR). Theoretically, I will discuss how to compute universal CSR distributions for non-Hermitian random matrices and uncorrelated random variables. Numerically, I will show how we can use CSR distributions to probe chaos and integrability in several open many-body quantum systems. Experimentally, I will review a recent experiment where, employing gradient-based tomography, we retrieved the CSR distributions for chaotic and integrable dissipative circuits. Increasing circuit depth induces an integrability-to-chaos crossover, demonstrating that intrinsic hardware noise is itself a source of dissipative quantum chaos. Together, our results reveal universal spectral features of dissipative many-body systems and establish modern quantum processors, typically used for unitary simulations, as a new experimental platform for dissipative quantum chaos.

Closed- and open-system characterization of the Yukawa–SYK model in real time

Speaker: Alex Windey

The Yukawa–SYK model—M bosons coupled to N fermions by random Yukawa vertices—is a solvable model of chaotic matter without quasiparticles, in which the interaction dynamically cancels the bare boson mass and generates a conformal non-Fermi liquid. Its vertex is the ordinary boson–fermion one, which makes it a realistic target for cavity QED platforms, where dissipation is unavoidable. Solving the saddle point equations on the Schwinger-Keldysh contour, we map out the phase diagram of the model, recovering the conformal and impurity/SYK_2 regimes and identify a driven-fermion regime, reproduced exactly by a quadratic SYK_2 model with time-dependent random hopping. We then construct a set of experimentally accessible markers that can separate the different regimes, in particular the conformal regime, and detect crossovers between them. Coupling the boson to a bath, only its static self-energy shift and its low-frequency exponent survive in the infrared. We show that the capacity of the fermions to soften the boson satisfies a bound fixed by the system alone, independent of the environment, giving an explicit bound on the temperature and loss rate at which self-tuned criticality can be observed.

Dissipation and the fate of chaos in a cavity-QED SYK model

Speaker: David Pascual Solis

The complex Sachdev–Ye–Kitaev model can be realised by a degenerate Fermi gas occupying the motional modes of a harmonic trap inside a multimode optical cavity. Virtual photon exchange through the transverse cavity modes mediates the all-to-all quartic interaction, while a speckle light shift on the atomic transition randomises the amplitudes. The adiabatic elimination that yields this effective Hamiltonian also yields two dissipative channels, cavity loss and spontaneous emission, whose jump operators are fermion bilinears built from the same overlap integrals. The dissipation is therefore neither weak nor generic. I study the complex eigenvalue statistics of the associated Lindbladian, which interpolate between the Poisson and Ginibre universality classes, to establish whether the chaotic character of the closed model persists once the system is opened.

Deep thermalization and measurements of quantum resources

Speaker: Naga Dileep Varikuti

Quantum resource theories provide a unified framework for characterizing useful quantum phenomena subject to physical constraints, but remain notoriously difficult to assess in experimental systems. We discuss an experimentally viable protocol for quantifying the resource content of arbitrary quantum evolutions across multiple resource theories. Central to our approach is the use of projected ensembles, recently employed to probe deep thermalization, which enable the construction of an unbiased estimator for entropy-based resource measures. We show that the estimator is highly reliable, with a signal-to-noise ratio that remains stable and scales exponentially with the number of qubits measured at the end of the protocol. Our work connects deep thermalization with resource quantification, offering a new perspective on the role of quantum resources in the emergence of state designs and providing an experimentally accessible route to their efficient estimation.

Dynamics and phase transitions in non-reciprocal quantum matter

Speaker: Pietro Brighi

Directionality and non-reciprocity are emerging as fascinating topics in open quantum many-body systems. In this talk, I will address recent progress in understanding the robustness of non-reciprocity in the presence of competing interactions. First, I will discuss reservoir engineering as a method to obtain non-reciprocal hopping and present how this changes in presence of interactions. In particular, I will show how interactions affect particles' dynamics and how one can control directionality of particles and quasi-particles using reservoir engineering. In the second part of the talk, I will present recent results on a solvable model, namely the non-reciprocal Kitaev chain. Here, pairing and non-reciprocal hopping compete, giving rise to a pairing-induced phase transition. The two phases affect both the dynamics and steady state of the system, showcasing how introducing superconducting pairing allows to investigate novel non-reciprocal phenomena.

Diagnosing non-Hermitian many-body localization and quantum chaos via singular value decomposition

Speaker: Federico Roccati

Strong local disorder in interacting quantum spin chains can turn delocalized eigenmodes into localized eigenstates, giving rise to many-body localized phases. This is accompanied by distinct spectral statistics: chaotic for the delocalized phase and integrable for the localized phase. In isolated systems, localization and chaos are defined through a web of relations among eigenvalues, eigenvectors, and real-time dynamics. These may change as the system is made open. We ask whether random dissipation (without random disorder) can induce chaotic or localized behavior in an otherwise integrable system. The dissipation is described using non-Hermitian Hamiltonians, which can effectively be obtained from Markovian dynamics conditioned on null measurement. In this non-Hermitian setting, we argue in favor of the use of the singular value decomposition. We complement the singular value statistics with different diagnostic tools, namely, the singular form factor and the inverse participation ratio and entanglement entropy of singular vectors. We thus identify a crossover of the singular values from chaotic to integrable spectral features and of the singular vectors from delocalization to localization. Our method is illustrated in an XXZ Hamiltonian with random local dissipation.

Tuesday, September 15 th

The flow of energy and Fisher information in complex media

Speaker: Stefan Rotter

Light propagating through a complex medium transports energy, and the local Poynting flux of a fully developed vectorial speckle field turns out to follow a universal statistical law that is fixed entirely by four eigenvalues of an electromagnetic covariance matrix. These eigenvalues encode forward transport, optical backflow and polarization mixing, and the law holds well beyond the paraxial and isotropic limits studied so far[1]. I will then introduce a second, less familiar current: the flow of Fisher information. This quantity sets, through the Cramér–Rao bound, the ultimate precision with which a parameter of an object hidden inside the medium can be estimated, and it has recently been shown to obey a continuity equation of its own[2]. Based on these insights, one can understand how information is generated at an object and how plasmonic or dielectric resonators can amplify this information and steer its flow[3]. I will show that this information currently obeys the very same universal statistics as the energy flow, and that its direction reverses across the object where it is created[1].

***References*:**

(1) Y. Ke, N. Bhattacharya, S. Rotter, F. Maucher, Universal statistics of energy and information flow in random electromagnetic fields, arXiv:2607.24631 (2026); (2) J. Hüpfl, F. Russo, L. M. Rachbauer, D. Bouchet, J. Lu, U. Kuhl, S. Rotter, Continuity equation for the flow of Fisher information in wave scattering. *Nature Physics* 20, 1294 (2024); (3) M. Weimar, H. Zhou, L. Neubacher, T. A. Grant, J. Hüpfl, K. F. MacDonald, S. Rotter, N. I. Zheludev, arXiv:2508.13640 (*Nature Materials*, provisionally accepted).

Quantum fluids of light

Speaker: Iacopo Carusotto

In this talk I will review the state of the art of the theoretical and experimental study of quantum fluids of light, namely assemblies of many photons that interact via the optical nonlinearity of the underlying medium, and I will highlight the crucial role of the driven-dissipative condition in shaping their many-body properties. Speculations in the direction of exploiting the peculiar tools of quantum optics to investigate chaotic behaviours will be finally discussed.

Monitoring low-rank SYK in a dissipative cavity: photon loss, quantum chaos, and quantum trajectories

Speaker: Pietro Pelliconi

The Sachdev-Ye-Kitaev model is an all-to-all interacting disordered model whose relevance ranges from quantum chaos to holographic quantum gravity. Cavity-QED platforms offer a promising route toward implementing closely related boson-fermion models, commonly known as Yukawa-SYK, in which cavity modes mediate all-to-all interactions through disordered QED-like vertices. In the dispersive regime, these systems realize an effective low-rank SYK dynamics for the fermionic degrees of freedom. In this presentation, we study the effect of photon loss on the quantum chaotic dynamics of low-rank SYK. Photon loss is a natural dissipative channel in cavity QED, but in this setting it plays a particularly interesting role: the same cavity modes that mediate the chaotic all-to-all interactions also provide the dominant channel through which information leaks out of the system. This creates an interplay between scrambling, relaxation, and measurement. We present results for two-point and four-point correlation functions in this dissipative regime, with the goal of understanding how photon loss modifies anomalous relaxation, out-of-time-ordered correlators, and Lyapunov growth. We then discuss the unraveling of quantum trajectories, in particular photon-detection statistics. Under natural assumptions, the waiting-time distribution of emitted photons encodes thermal information about the effective low-rank SYK model, allowing one to reconstruct its partition function.

Finite steady-state currents and multipole skin effects challenge non-Hermitian localization

Speaker: Federico Balducci

Non-Hermitian many-body localization has emerged as a possible scenario for chaos suppression in open systems, as suggested by spectral indicators identifying a putative transition for finite system sizes. In the first half of this talk, I will shift the focus to dynamical probes, specifically the steady-state spin current, to investigate transport properties in a disordered, non-Hermitian XXZ spin chain. Through exact diagonalization for small systems and tensor-network methods for larger chains, we demonstrate that the steady-state current remains finite and decays exponentially with disorder strength, showing no evidence of a transition up to disorder values far beyond the previously claimed critical point. In the second half of the talk, I will instead focus on the competition between disorder and a particular kind of non-Hermitian skin effect, which takes place in systems that conserve both a U(1) charge and its associated multipole moments. If dipoles or higher multipoles are conserved, we show that the non-Hermitian skin effect remains stable to arbitrary disorder, meaning that the system is always delocalized under periodic boundary conditions, regardless of disorder strength.

***References*:**

P. Brighi, M. Ljubotina, F. Roccati and FB, *Phys. Rev. Research* 7, L042014 (2025); J. Gliozzi, FB, T. L. Hughes, & G. De Tomasi, Phys. Rev. B 113, L100203 (2026).

Collective dynamics in spin chains with constrained dissipation

Speaker: Alberto Biella

Collective non-equilibrium phenomena in many-body systems are strongly influenced by fluctuations, particularly in the vicinity of phase transitions, where the interplay between classical and quantum fluctuations can alter cooperative behavior. Here, we investigate this competition in a kinetically constrained spin chain, paradigmatic in the exploration of physics far from equilibrium. We find that augmenting the dissipative far-East model with quantum fluctuations leads to the stabilization of a previously transient metastable phase and, as their strength increases, trigger a transition into a monostable phase. We explore the steady-state phase diagram using a cluster mean-field approach and characterize the dynamics with stochastic tensor-network methods. Within the bistable phase we identify signatures of dynamical heterogeneity in the local magnetization as well as in the entanglement dynamics. This highlights how competing quantum fluctuations and classical kinetic constraints shape the relaxation dynamics and the phase structure of many-body systems.

Two steps aside: From quantum to classical (experimental) chaos

Speaker: Leonardo Ricci

For sure quantum and classical chaos share a noun. However a longstanding question concerns how deeply the two fields are mutually related. After a recap of the major aspects that set the two manifestations of chaos apart, indeed more than joining them, an overview of classical chaos is discussed, with a special attention on its occurrence in neural networks. The final section is devoted to the old and new methods that allow to detect a chaotic behavior in a system by observing the signals it produces.

Resisting chaos: quantum resources and noise in quantum annealing

Speaker: Chiara Capecci

Quantum annealing aims to prepare the ground state of an optimization problem through an adiabatic evolution that, rather than thermalizing, ideally follows a single eigenstate from a simple initial Hamiltonian to the final problem Hamiltonian. Quantum resources — in particular, nonstabilizerness — provide a way to characterize the complexity of the quantum states generated during this evolution. Along adiabatic sweeps, the state crosses a characteristic “magic barrier” that remains well below the Haar-random value and is not determined by the minimum energy gap. Non-stoquastic catalysts that circumvent exponentially closing gaps do not reduce these quantum resources, indicating that improved adiabatic accessibility does not necessarily translate into easier classical simulation. Finally, the effect of magnetic-field noise is investigated on a trapped-ion (MAGIC) quantum annealer. Dynamical decoupling, implemented through periodic spin-flip pulses during the annealing sweep, strongly suppresses the effect of noise and restores near-ideal fidelity, with the dynamics exhibiting a universal scaling with the product of noise amplitude and pulse interval.

Observable signatures of exceptional points from left-right eigenstate distinction

Speaker: Leela Ganesh Chandra Lakkaraju

Non-Hermitian quantum systems exhibit qualitatively distinct physical behavior compared to Hermitian systems, a prime example being spectral singularities known as exceptional points. Their relevance in, e.g., quantum sensing, unidirectional transport, and robust lasing makes it important to be able to identify exceptional points through observable features of a many-body system. Here, using as an example a one-dimensional complex XY spin chain realizing both rotation-time RT- and parity-time PT-symmetric regimes, we develop a framework for detecting exceptional points based on the distinction between left and right eigenvectors of the Hamiltonian, which in a non-Hermitian system are no longer the adjoint of each other. We first show that a global measure constructed from the difference between the Hamiltonian and its adjoint locates exceptional points via distinct non-analytic behavior. At the level of observables, differences in local spin correlations evaluated on the right and left eigenstates provide a reliable static detection scheme. In contrast, static bipartite entanglement measures fail to capture this distinction, urging us to study the quantum dynamics of the model. Following a sudden quench, we demonstrate that the time-averaged right-left entanglement entropy difference directly encodes signatures of the exceptional point. In the RT-symmetric regime, it exhibits a pronounced peak at the exceptional point, whereas in the PT-symmetric regime it behaves as an order-parameter-like quantity, remaining finite in one phase and vanishing at the transition. Our results establish a direct link between the structure of non-Hermitian eigenstates and observable signatures of exceptional points, providing a practical route to identify them in existing quantum simulators.

Quantum many-body scars under measurement and dissipation

Speaker: Alessandro Silva

Quantum many-body scars are a striking exception to thermalization: in constrained models like PXP, certain initial states fail to equilibrate and instead show long-lived periodic revivals. This robustness is usually expected to be fragile once the system is coupled to an environment. I will show that this intuition is incomplete. Drawing on measurement-induced phase transitions, I discuss how periodic projective measurements can resynchronize and enhance scarred revivals, while random measurements suppress them. I then turn to genuinely dissipative dynamics, showing that Markovian jump operators respecting the same kinetic constraint as the Hamiltonian leave the scar tower and its revival period intact, with asymmetric, spatially structured dissipation further protecting it from thermalization.