TT 1: Focus Session: New Routes to Localization and Quantum Non-Ergodicity I (joint session TT/DY)

This session explores how quantum many-body systems can fail to thermalize through mechanisms that extend beyond conventional many-body localization. Recent work has discovered new mechanisms that lead to non-ergodic behavior, including Hilbert-space fragmentation, disorder-free localization, and confinement effects that arise from destructive interference in Fock space. At the same time, experiments with ultracold atoms, trapped ions, Rydberg platforms, and superconducting qubits directly reveal many-body scars, slow relaxation, and unusual transport. This session highlights these developments and identifies the central open questions that are now driving the field forward.

Coordinators: Roderich Moessner (MPI PKS Dresden), Frank Pollmann (TU München)

Time: Monday 9:30–12:15 Location: HSZ/0003

Topical Talk TT 1.1 Mon 9:30 HSZ/0003

Eigenstate thermalization in thermal first-order phase transitions — •Maksym Serbyn — IST Austria, Am Campus 1, 3400 Klosterneuburg

In my talk I will discuss the fate of eigenstates in quantum systems in vicinity of thermal first order phase transition. The eigenstate thermalization hypothesis (ETH) posits how isolated quantum many-body systems thermalize, assuming that individual eigenstates at the same energy density have identical expectation values of local observables in the limit of large systems. In my talk I will show that ETH requires generalization in the presence of thermal first-order phase transitions. I will argue that for energies in the vicinity of the thermal phase transition, eigenstate expectation values do not need to converge to the same thermal value. The system has a regime with coexistence of two classes of eigenstates corresponding to the two branches with distinct expectation values at the same energy density, and another regime with Schrodinger-cat-like eigenstates that are inter-branch superpositions; these two regimes are separated by an eigenstate phase transition. I will also discuss potential extensions of these results to more physical models, and outline how the special structure of eigenstates near first order phase transition can be probed via quench dynamics.

Topical Talk TT 1.2 Mon 10:00 HSZ/0003

Stabilizing Floquet orders to infinite time — •Anushya Chandran[1], Shreyas Raman[2], Robin Schäfer[3], and Alicia Kollàr[4] — [1]Boston University, Boston, USA — [2]Boston University, Boston, USA — [3]Helmholtz-Zentrum Berlin, Berlin, Germany — [4]University of Maryland, College Park, USA

Floquet engineering, in which the properties of a quantum system are modified through the application of strong periodic drives, is an indispensable tool in atomic and condensed matter systems. It enables quantum simulation, the dynamic stabilization of unstable states, and the realization of exotic topological order and time crystals. However, it is inevitably limited by intrinsic heating processes, so that the engineered states are, at best, pre-thermal. I will describe a general-purpose dissipative scheme that autonomously cools a strongly driven system to close to a desired Floquet engineered state. I will demonstrate this stabilization in a driven many-body spin chain, that either spontaneously breaks a symmetry or exhibits discrete time-crystalline order in the steady state.

Topical Talk TT 1.3 Mon 10:30 HSZ/0003

Dynamical landscape of out of equilibrium emergent lattice gauge theories in two dimensions — •Nilotpal Chakraborty — University of Cambridge

Many-body models with local constraints, such as dimer, ice or generally quantum link type models often are described as emergent gauge theories. I will describe a range of recent results, comprising classical and quantum dynamics of different kind, highlighting the rich dynamical phenomenology present in these models. In line with the session's topic, I will focus more on the two-dimensional U(1) quantum link model, and highlight its potential as a new route toward localisation and non-ergodicity in the absence of quenched disorder. In doing so, I will also present spectral signatures of such localization. Finally, I will end by discussing possibilities of realising the different constrained models and their dynamics in quantum simulators, for which there appears to be palpable current interest.

15 min. break

Topical Talk TT 1.4 Mon 11:15 HSZ/0003

Interference, topology, and new Hilbert-space routes to quantum non-ergodicity — •Yi-Ping Huang[1,2,3] and Tao-Lin Tan[1] — [1]Department of Physics, National Tsing Hua University, Hsinchu 30013, Taiwan — [2]Physics Division, National Center for Theoretical Sciences, Taipei 10617, Taiwan — [3]Institute of Physics, Academia Sinica, Taipei 115, Taiwan

A central challenge in nonequilibrium quantum physics is to understand why certain many-body systems fail to thermalize even in the absence of disorder or integrability. In this talk, I will outline a different perspective in which non-ergodicity is governed by hidden geometric structures in Hilbert space rather than by conventional real-space mechanisms. This viewpoint leads to the concept of interference-caged quantum many-body scars (ICQMBS), where exact many-body destructive interference confines eigenstates to small regions of the Fock-space graph. Remarkably, interference zeros and graph automorphisms emerge as universal organizing principles, revealing a class of topological ICQMBS whose robustness originates from local Fock-space topology rather than symmetries or constraints. This framework not only explains diverse non-ergodic phenomena from one-dimensional systems to two-dimensional gauge models but also provides new tools for systematically identifying them. I will end with a brief look at stabilizing QMBS through the lens of Kramers-Wannier duality, illustrating the challenges and possibilities that arise when studying QMBS under duality.

Topical Talk TT 1.5 Mon 11:45 HSZ/0003

Fock-space cages and their spectral signatures — •Cheryne Jonay — University of Ljubljana

Generic quantum many-body systems thermalize. Yet several mechanisms can prevent this, notable examples include integrability, many-body localization, Hilbert-space fragmentation, and scars. We will discuss a new mechanism of ergodicity breaking that arises from destructive interference in Fock space. This leads to exact eigenstates localized on polynomially many configurations within an exponentially large, fully connected Hilbert space sector. We call these states Fock-space cages. They emerge naturally in kinetically constrained models with chiral symmetry. We will present graph-theoretic methods to explicitly construct cages with support ranging from O(1) to O(L) sites, and examine how their dynamical signatures, such as return probabilities and magnetization, resist thermalization. Finally, we will explore the spectral statistics through the lens of chiral random matrix theory. The exponentially degenerate zero-energy manifold produces distinctive signatures, yet the agreement with random matrix predictions varies across energy scales - a direct consequence of localized and thermal eigenstates coexisting within the same Hilbert space sector. We will also probe the stability of these phenomena: the gap between the zero-energy manifold and the spectral bulk may give rise to protected slow dynamics.