Symposium Quantum Thermalization (SYQT)

Fabian Heidrich-Meisner
University of Göttingen
Friedrich-Hund-Platz 1
37077 Göttingen, Germany
fabian.heidrich-meisner@uni-goettingen.de

Frank Pollmann
Technical University of Munich
James-Franck-Straße 1
85748 Garching, Germany
frank.pollmann@tum.de

Why and how do isolated quantum systems thermalize-or fail to do so? This fundamental question lies at the heart of current research in quantum many-body physics. While the eigenstate thermalization hypothesis (ETH) has provided a framework for understanding quantum chaos and ergodicity, a growing class of systems defies this paradigm. Constrained dynamics can lead to rich and exotic behaviors such as Hilbert-space fragmentation, quantum many-body scars, and anomalous transport.

This symposium covers advances in statistical physics, condensed matter, quantum optics, and lattice gauge theories. The talks will highlight both foundational insights and new experimental platforms, including experiments tailored to realize lattice gauge theories and advanced quantum-gas microscopes, complemented by theoretical talks. The theoretical talks will bridge between quantum thermalization in quantum simulators and high-energy physics.

Overview of Invited Talks and Sessions

(Lecture hall ZHG104)

Invited Talks

SYQT 1.1	Wed	10:45–11:15	ZHG104	**Probing quantum many-body dynamics using subsystem Loschmidt echos** — •Monika Aidelsburger
SYQT 1.2	Wed	11:15–11:45	ZHG104	**Approach to thermalisation in the Schwinger model** — •Adrien Florio
SYQT 1.3	Wed	11:45–12:15	ZHG104	**Timescales for thermalization and many-body quantum chaos** — •Lea Santos
SYQT 1.4	Wed	12:15–12:45	ZHG104	**Observation of Hilbert-space fragmentation and fractonic excitations in tilted Hubbard models** — •Johannes Zeiher

Sessions

SYQT 1.1–1.4	Wed	10:45–12:45	ZHG104	**Quantum Thermalization**

SYQT 1: Quantum Thermalization

Time: Wednesday 10:45–12:45 Location: ZHG104

Invited Talk SYQT 1.1 Wed 10:45 ZHG104

Probing quantum many-body dynamics using subsystem Loschmidt echos — •Monika Aidelsburger — MPQ Garching, Germany — LMU Munich, Germany

Neutral atoms in optical lattices offer large system sizes and long coherence times, ideal for investigating out-of-equilibrium dynamics and fundamental questions about the thermalization of isolated quantum many-body systems. The Loschmidt echo - the probability of a quantum many-body system to return to its initial state following a dynamical evolution - generally contains key information about a quantum system, relevant across various scientific fields including quantum chaos, quantum many-body physics, or high-energy physics. However, it is typically exponentially small in system size, posing an outstanding challenge for experiments. Here, I introduce the subsystem Loschmidt echo, a quasi-local observable that captures key features of the Loschmidt echo while being readily accessible experimentally. In the short-time regime, we use it to reveal a dynamical quantum phase transition arising from genuine higher-order correlations. In the long-time regime, it quantitatively determines the effective dimension and structure of the accessible Hilbert space in the thermodynamic limit providing direct experimental evidence for ergodicity breaking due to Hilbert-space fragmentation. These findings establish the subsystem Loschmidt echo as a powerful tool to study out-of-equilibrium dynamics, applicable to a broad range of quantum simulation and computing platforms.

Invited Talk SYQT 1.2 Wed 11:15 ZHG104

Approach to thermalisation in the Schwinger model — •Adrien Florio — Bielefeld

The Schwinger model is a confining theory in one plus one dimensions that has a chiral condensate and a chiral anomaly. I will present tensor network simulations of its real-time dynamics. In particular, I will discuss how the system appears to thermalise when subjected to an inhomogeneous quench reminiscent of the production of hard particles in a QCD jet. I will characterise this approach to equilibrium through the lens of local observables and the rearrangement of entanglement in the system.

Invited Talk SYQT 1.3 Wed 11:45 ZHG104

Timescales for thermalization and many-body quantum chaos — •Lea Santos — University of Connecticut, Storrs, CT, USA

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.

Invited Talk SYQT 1.4 Wed 12:15 ZHG104

Observation of Hilbert-space fragmentation and fractonic excitations in tilted Hubbard models — •Johannes Zeiher — Ludwig-Maximilians-Universität München — Max-Planck-Institut für Quantenoptik

Neutral atoms trapped in optical lattices are a versatile platform to study many-body physics in and out of equilibrium. The relaxation behavior of isolated quantum systems taken out of equilibrium is among the most intriguing problems in many-body physics. Quantum systems out of equilibrium typically relax to thermal equilibrium states by scrambling local information and building up entanglement entropy. In this talk, I will present our recent experiments on probing an exception to this expected thermalization behavior in two-dimensional tilted Hubbard models with strong kinetic constraints. Combining local initial-state control with site-resolved measurements in our quantum-gas microscope, we find a strong dependence of the relaxation dynamics on the specific initial state - a hallmark of the shattering of the underlying Hilbert space in disconnected fragments. Leveraging the control over individual atoms, we furthermore inject mobile excitations into an otherwise immobile state and track their dynamics. We find subdimensional dynamics, which is a feature characteristic of fractonic excitations. Our results pave the way for in-depth studies of microscopic transport phenomena in constrained systems.