TT 19: Focus Session: New Routes to Localization and Quantum Non-Ergodicity II (joint session TT/DY)

Time: Monday 15:00–17:30 Location: CHE/0091

TT 19.1 Mon 15:00 CHE/0091

Localized obstructed pairs with zero superfluid stiffness from doping an antiferromagnetic insulator — •Tamaghna Hazra[1], Nishchhal Verma[2], and Jörg Schmalian[1] — [1]Institüt für Theorie der Kondensierten Materie, Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Department of Physics, Columbia University

Doping a Mott antiferromagnet is widely expected to yield mobile Cooper pairs whose kinetic energy sets the superfluid stiffness. We show instead that, when doped charges propagate on the line graph of a lattice with strong antiferromagnetic exchange, they bind into *obstructed* Cooper pairs, which are compact localized bosons that possess *zero* superfluid stiffness at leading order in the strong-coupling expansion. The pair-hopping Hamiltonian generates an exactly flat bosonic band whose compact localized states dominate the low-energy Hilbert space, yielding a ground-state manifold with extensive degeneracy and a phase stiffness that vanishes anomalously as the *third* inverse power of the pairing strength in the strong-coupling limit. At quarter filling, the frustrated dynamics maps onto a quantum dimer model at the Rokhsar-Kivelson point, realizing a d-wave resonating-valence-bond spin liquid with topological ground-state degeneracy and deconfined holon excitations. Our results establish a mechanism for interaction-driven localization without disorder, in which strong magnetically-mediated pairing produces Cooper pairs whose kinetic energy collapses to zero, revealing a distinct failure mode of unconventional superconductivity in strongly-correlated materials.

TT 19.2 Mon 15:15 CHE/0091

Disorder-free localization from mass-imbalanced fractionalization — •Shi Feng, Johannes Knolle, and Michael Knap — Technical University of Munich, Garching, Germany

We report disorder-free localization of Majorana fermions over intermediate timescales in an emergent gapless non-integrable Z_2 quantum liquid. A large density of heavy visons induced by an external magnetic field provides coherent disorder that localizes the light fermions while preserving translation symmetry. Compelling evidence of the localization within intermediate time scale is provided by the time evolution of the local energy density, which shows negligible spreading after a local quench on its ground state; and a vanishing energy current response despite the gapless energy spectrum. These results demonstrate that the disorder-free localization can also occur near equilibrium at low energy, and offer an explanation to the thermal paradox in recent experiments where a linear specific heat coexists with vanishing thermal transport in frustrated Mott insulators with disorder-free gapless quantum magnets.

TT 19.3 Mon 15:30 CHE/0091

Fock space fragmentation in quenches of disordered interacting fermions — •Ishita Modak[1], Rajesh Narayanan[2], Ferdinand Evers[3], and Soumya Bera[1] — [1]Department of Physics, Indian Institute of Technology Bombay, Mumbai, India. — [2]Department of Physics, Indian Institute of Technology Madras, Chennai, India — [3]Institute of Theoretical Physics and Halle-Berlin-Regensburg Cluster of Excellence CCE, University of Regensburg, Regensburg, Germany

Hilbert space fragmentation primarily originates from specific kinematic constraints or emergent conservation laws in many-body systems with translation invariance. It leads to non-ergodic dynamics and breakdown of the eigenstate thermalization hypothesis. We demonstrate that also in disordered systems (e.g. random-field XXZ model), fragmentation appears as a natural concept offering fresh perspectives on many-body delocalization (MBdL). We split the Fock-space into potential-energy shells, which contain the accessible phase space for the relaxation of a quenched initial state. In this construction, dynamical observables reflect properties of the shell geometry, e.g., the drastic sample-to-sample fluctuations observed in the weak disorder regime, $W < W_c$, represent fluctuations of the shell-mass. Upon crossing over to strong disorder, $W > W_c$, the potential-energy shell decays into fragments; we argue that, unlike percolation, fragmentation is a strong-coupling scenario with turn-around flow: $W_c(L)$ diverges with increasing system size. We conjecture that the slowing down of the relaxation dynamics reported in traditional MBdL studies is a manifestation of Fock-space fragmentation introduced here.

TT 19.4 Mon 15:45 CHE/0091

Non-ergodic one-magnon magnetization dynamics of the Kagome lattice antiferromagnet — Henrik Schlüter, •Jannis Eckseler, and Jürgen Schnack — Bielefeld University

The present view of modern physics on non-equilibrium dynamics is that generic systems equilibrate or thermalize under rather general conditions, even closed systems under unitary time evolution. The investigation of exceptions thus not only appears attractive, in view of quantum computing where thermalization is a threat it also seems to be necessary. Here, we present aspects of the one-magnon dynamics on the Kagome lattice antiferromagnet as an example of a non-equilibrating dynamics due to flat bands. Similar to the one-dimensional delta chain localized eigenstates also called localized magnons lead to disorder-free localization and prevent the system from thermalization [1].

[1] H. Schlüter, J. Schnack and J. Eckseler, Zeitschrift für Naturforschung A (2025) doi:10.1515/zna-2025-0249

TT 19.5 Mon 16:00 CHE/0091

Cooling dynamics of a disorder-free localized Kitaev model — •Arkadeep Mitra, Francesco Piazza, and Markus Heyl — Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

The Kitaev spin-1/2 model on a 2D honeycomb lattice has a Z_2 gauge symmetry that translates to an effective picture of free Majorana fermions on a background static charge field. This yields a ground state that realizes a quantum spin liquid (QSL) with fractional excitations. At high temperatures, however, it has recently been observed to enter a disorder-free localized phase, so that any experimental cooling of a Kitaev material has to cross this localized and associated phase transition. Motivated from this, we study theoretically the cooling dynamics upon coupling the Kitaev model to phonons with a symmetry breaking interaction. We envisage that signatures obtained from this dynamics could act as probes for QSL.

15 min. break

TT 19.6 Mon 16:30 CHE/0091

Scrambling signature of scars — •Thomas Michel[1], Mathias Steinhuber[2], Juan Diego Urbina[2], and Peter Schlagheck[1] — [1]Université de Liège, Liège, Belgique — [2]Universität Regensburg, Regensburg, Germany

We study signatures of scrambling, such as out-of-time-ordered correlators, that are associated with weakly unstable periodic orbits in a mixed or chaotic classical phase space, fulfilling Heller's criterion [1] for the existence of scars. As verified within generic dynamical systems like the kicked rotor and the driven pendulum, evaluating scrambling observables for coherent states centred in phase space about such periodic orbits gives rise to characteristic scar features both in the short and long time regimes, the latter amounting to a significant amendment of the characteristic growth exponent with respect to the generic semiclassical prediction [2,3]. Extensions to many-body scars in Bose-Hubbard rings [4] are discussed.

[1] E. J. Heller, Phys. Rev. Lett. 53, 1515 (1984).
[2] J. Rammensee, J.-D. Urbina, and K. Richter, Phys. Rev. Lett. 121, 124101 (2018).
[3] T. R. Michel, J. Diego Urbina, and P. Schlagheck, J. Phys. A: Math. Theor. 58, 275303 (2025).
[4] Q. Hummel, K. Richter, and P. Schlagheck, Phys. Rev. Lett. 130, 250402 (2023).

TT 19.7 Mon 16:45 CHE/0091

Many-Body Cages - Flat bands on the state graph — •Tom Ben-Ami[1,2], Markus Heyl[1], and Roderich Moessner[2] — [1]University of Augsburg, D-86135 Augsburg, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, Dresden 01187, Germany

We identify the many-body counterpart of flat bands, which we term many-body caging, as a general mechanism for non-equilibrium phenomena such as a novel type of glassy eigenspectrum order and many-body Rabi oscillations in the time domain. We focus on constrained systems of great current interest in the context of Rydberg atoms and synthetic or emergent gauge theories. We find that their state graphs host motifs which produce flat bands in the many-body spectrum at a particular set of universal energies. Basis states in Fock space exhibit Edwards-Anderson type order in the absence of quenched disorder, with an intricate, possibly fractal, distribution over Fock space. This is reflected in a distinctive structure of a non-vanishing post-quench long-time Loschmidt echo, an experimentally accessible quantity. In general, phenomena familiar from single-particle flat bands manifest themselves in characteristic many-body incarnations, such as a reentrant 'Anderson' delocalisation, offering a rich ensemble of experimental signatures in the abovementioned quantum simulators. The variety of single-particle flat band types suggests an analogous typology–and concomitant phenomenological richness to be explored–of their many-body counterparts.

TT 19.8 Mon 17:00 CHE/0091

Dynamics in the presence of local symmetry-breaking impurities — •Yahui Li[1,2], Pablo Sala[3,4], Frank Pollmann[1,2], Sanjay Moudgalya[1,2], and Olexei Motrunich[3,4] — [1]Technical University of Munich, Germany — [2]Munich Center for Quantum Science and Technology, Germany — [3]California Institute of Technology, USA — [4]Walter Burke Institute for Theoretical Physics, USA

Continuous symmetries lead to universal slow relaxation of correlation functions in quantum many-body systems. In this talk, I will show how local symmetry-breaking impurities affect the dynamics of these correlation functions using Brownian quantum circuits. While explicitly breaking the symmetry is generally expected to lead to eventual restoration of full ergodicity, we find that approximately conserved quantities that survive under such circumstances can still induce slow relaxation. This can be understood using a super-Hamiltonian formulation, where low-lying excitations determine the late-time dynamics. We show that in one dimension, symmetry-breaking impurities modify diffusive and subdiffusive behaviors associated with U(1) and dipole conservation at late times, e.g., by increasing power-law decay exponents of the decay of autocorrelation functions. On the other hand, for an impurity that disrupts strong Hilbert space fragmentation, it leads to prethermal plateaus in autocorrelation functions. Overall, our approach systematically characterizes how symmetry-breaking impurities affect relaxation dynamics in symmetric systems.

TT 19.9 Mon 17:15 CHE/0091

Late time dynamics of quantum entanglement — •Felix Dusel[1,2], Frank Pollmann[1,2,3], Tobias Micklitz[4], and Alexander Altland[5] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Munich Quantum Valley, 80807 Munich, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, 80799 Munich, Germany — [4]Centro Brasileiro de Pesquisas Físicas, Rua Xavier Sigaud 150, 22290-180 Rio de Janeiro, Rio de Janeiro, Brazil — [5]Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Cologne, Germany

We study entanglement spreading in quantum circuits composed of local qudits with large Hilbert space dimension, and single-particle dynamics relaxing slower than the characteristic timescale for entangling of neighboring qudits.