TT 21: Focus Session: Quantum Dynamics of Kinetically Constrained Many-Body Systems (joint session TT/DY)

Over the past few years it has been shown that quantum many-body systems far from equilibrium can exhibit very rich and exciting physics, including the emergence of thermodynamics in closed quantum systems, dynamical quantum phase transitions, and many-body localization. This topic became of particular relevance as closed quantum many body states can now be prepared experimentally and coherent quantum dynamics can be observed over long time scales. Strongly correlated systems that are subject to a kinematic constraints receive currently a lot of attention. Such constrained quantum matter is characterized by a Hilbert space structure that is different from a conventional tensor product structure. Well known examples are frustrated quantum magnets described by effective dimer models, fractional quantum Hall liquids, and so called fracton models with excitations that are only mobile in certain directions. In a recent experiment, constrained models have also been realized in synthetic quantum matter in which Rydberg excitations of one-dimensional ultracold atoms are energetically forbidden to occupy neighbouring sites*a constrained model that can be mapped onto a 1D quantum dimer model. While the equilibrium properties of constrained systems have been studied in depth over the past decades in the context of frustrated magnetism and gauge theories, we just begin to understand the rich non-equilibrium physics of these systems. The proposed session aims to give an overview ofrecent developments and point towards the open questions.

Organized by: Michael Knap (Technical University of Munich), Frank Pollmann (Technical University of Munich), Roderich Moessner (Max-Planck-Institute for the Physics of Complex Systems)

Time: Tuesday 9:30–13:00 Location: H2

Invited Talk TT 21.1 Tue 9:30 H2

Quantum dynamics, scars, and integrability in constrained Rydberg systems — •Vedika Khemani[1], Christopher Laumann[2], and Anushya Chandran[2] — [1]Harvard University, Cambridge, Massachusetts, USA — [2]Boston University, Boston, Massachusetts, USA

A recent experiment on a 51-atom chain of Rydberg atoms observed anomalously long-lived temporal oscillations of local observables after quenching from an antiferromagnetic initial state. This coherence is surprising as the initial state should have thermalized rapidly to infinite temperature. I will describe the novel dynamics of this system using various diagnostics, and provide some insights into the underlying causes for the unusual dynamical properties of this system.

Invited Talk TT 21.2 Tue 10:00 H2

DMRG investigation of constrained models: from quantum dimer and quantum loop ladders to hard-boson and Fibonacci anyon chains — •Natalia Chepiga[1] and Frederic Mila[2] — [1]University of California, Irvine, USA — [2]EPFL, Lausanne, Switzerland

Motivated by the presence of Ising transitions that take place entirely in the singlet sector of frustrated spin-1/2 ladders and spin-1 chains, we study two types of effective dimer models on ladders, a quantum dimer model and a quantum loop model. We further show that both models can be mapped rigorously onto a hard-boson model first studied by Fendley, Sengupta and Sachdev [Phys. Rev. B 69, 075106 (2004)]. Building on a density-matrix renormalization group algorithm that takes full advantage of the dimers constraints, we study systems with up to 9'000 sites and calculate the correlation length and the wave-vector of the incommensurate short-range correlations with unprecedented accuracy. We discuss the full phase diagram of these models, with special emphasis on the phase transitions. In particular, we provide strong numerical evidence that there is an intermediate floating phase far enough from the integrable Potts point, while in its vicinity, our numerical data are consistent with a unique transition in the Huse-Fisher chiral universality class. Moreover, using conformal field theory, we fully characterize the tricritical Ising point, with a complete analysis of the boundary-field correspondence including partially polarized edges.

Invited Talk TT 21.3 Tue 10:30 H2

Localization in Fractonic Random Circuits — Shriya Pai, •Michael Pretko, and Rahul Nandkishore — University of Colorado Boulder

In this talk, I will describe a new mechanism for many-body localization, making use of ideas drawn from the field of fractons. Specifically, I will present results on the spreading of initially local operators under random unitary evolution in spin chains subject to fracton conservation laws, such as conservation of dipole moment. We find that fractons remain permanently localized at their initial positions, providing a crisp example of a non-ergodic dynamical phase of random unitary evolution. These results can be interpreted as a consequence of the properties of low-dimensional random walks. This mechanism for localization remains robust in one and two dimensions, but breaks down in three-dimensional fracton systems. We argue that these results extend to Floquet and Hamiltonian time evolution, even in the absence of disorder, thereby providing a mechanism for many-body localization in a translationally invariant system.

15 min. break.

Invited Talk TT 21.4 Tue 11:15 H2

Many-body localization dynamics from gauge invariance — •Markus Heyl — Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany

In this talk I will show how lattice gauge theories can display many-body localization dynamics in the absence of disorder as a consequence of local constraints induced by gauge invariance. The starting point is the observation that, for some generic homogeneous initial conditions, the time-evolved state can be decomposed into different superselection sectors as a consequence of Gauss law in such a way that it realizes an effective disorder average. By carrying out extensive exact simulations on the real-time dynamics of a lattice Schwinger model, describing the coupling between U(1) gauge fields and staggered fermions, it is shown that the dynamics can become nonergodic leading to a slow, double-logarithmic entanglement growth. These findings are immediately relevant to cold atoms and trapped ion experiments realizing dynamical gauge fields and suggest a new and universal link between confinement and entanglement dynamics in the many-body localized phase of lattice models.

Invited Talk TT 21.5 Tue 11:45 H2

Slow dynamics due to kinetic constraints, from classical to quantum — •Juan Garrahan — School of Physics and Astronomy, University of Nottingham

Classical many-body systems that display slow collective relaxation - the canonical example being those that form glass - often do so due to effective constraints in the their dynamics. The simplest manifestation of this principle is in so-called kinetically constrained models (KCMs) where dynamical constraints are explicit. After reviewing the basic properties of constrained dynamics in classical systems, I will dis- cuss how similar ideas can be made relevant for quantum many-body systems. I will describe quantum KCMs which display slow thermalization and even in certain cases (apparent) non-ergodicity in the absence of disorder. Like in the classical case, I will show how slow relaxation goes together with spatially fluctuating dynamics, giving rise to heterogeneous growth of entanglement. I will also discuss connections with other quantum systems with complex dynamics such as fracton models. My main aim will be to highlight links between concepts and methods of classical and quantum non-equilibrium.

TT 21.6 Tue 12:15 H2

Dynamical Phase Transitions in a 2D Quantum Dimer Model

— •Johannes Feldmeier, Michael Knap, and Frank Pollmann — Technische Universität München

The study of dynamical properties in systems with local constraints has attracted a lot of interest, spurred by experiments with Rydberg blockaded atoms, that naturally implement constrained many-body models. We study the quench dynamics in a 2D quantum dimer model to identify dynamical phase transitions in constrained models by means of exact diagonalization on systems of sizes up to 8x8 sites. We find that the quenched quantum system thermalizes efficiently by determining the relaxation dynamics of both the order parameter (OP) and local correlation functions. The observed fast relaxation to thermal expectation values allows us to study the underlying thermal BKT-transition between a columnar ordered valence bond solid (VBS) and a symmetric liquid (VBL) phase in the form of a dynamical phase transition. The existence of this finite-temperature transition in the dynamics is confirmed by the long-time averaged values of the OP. Moreover, upon quenching across the VBS-VBL phase boundary, the dynamical transition can be shown to be manifest in the Loschmidt-echo, whose rate-function displays kinks at the zero-crossings of the columnar OP.

TT 21.7 Tue 12:30 H2

Hamiltonian systems with charge and dipole conservation far from equilibrium

— •Pablo Sala, Tibor Rakovszky, Ruben Verresen, Michael Knap, and Frank Pollmann — Technische Universität München, Physics Department T42, 85747 Garching, Germany

Recently so-called fracton phases, which are characterized by excitations with restricted mobility, have been discovered. The mobility constraints are related to the conservation of a U(1) charge and its associated dipole moment. Motivated by results on random unitary circuits [1], we study one dimensional spin-1/2 and spin-1 Hamiltonian systems conserving these two intertwined quantities and consider the implications of a U(1) local gauge invariance. We investigate the effects of these conservation laws on the dynamics, and the implications for higher dimensional systems following the same construction.

[1] S. Pai, M. Pretko and R. M. Nandkishore. arXiv:1807.09776 [cond-mat.stat-mech]

TT 21.8 Tue 12:45 H2

Apparent slow dynamics in the ergodic phase of a driven many-body localized system without extensive conserved quantities

— •Talía Lezama Mergold Love[1], Soumya Bera[2], and Jens H. Bardarson[1,3] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Department of Physics, Indian Institute of Technology Bombay, Mumbai 400076, India — [3]Department of Physics, KTH Royal Institute of Technology, Stockholm, 106 91 Sweden

One of the distinguishing features of the ergodic phase in systems exhibiting many-body localization (MBL) is a slowing down of the dynamics as they approach the MBL transition. Using a fast Walsh-Hadamard transform, we numerically study the former scenario in a Floquet model with no global conservation laws. In this model, the ergodic-MBL transition can be tuned by the disorder strength within a region of the frequency-amplitude space. Similarly to models with conserved quantities, our data is consistent with a subballistic spread of entanglement and a stretched-exponential decay of an autocorrelation function, with their associated exponents reflecting slow dynamics near the transition for a fixed system size. However, with access to larger system sizes, we find a clear flow of the exponents towards faster dynamics. We further observe examples of non-monotonic dependence of the exponents with time, consistent with the slow dynamics being a crossover phenomena with a localized critical point.