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Interacting Many-Body Spin Systems that Fail to Quantum Thermalize

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This talk will describe the experimental observation of two mechanisms – many-body localization (MBL) and prethermalization – that prevent interacting quantum systems from attaining thermal equilibrium. Effective magnetic spins are encoded within the long-coherence-time electronic states of trapped ions, which are measured with nearly perfect efficiency. Tunable, long-range interactions are generated across the entire chain using state-dependent optical dipole forces. MBL states are created by applying random, site-dependent disorder in the presence of a long-range interacting Ising Hamiltonian, while prethermal states arise in the presence of a long-range interacting XY-model Hamiltonian. In both scenarios, the system retains strong memory of its initial conditions and cannot be well-described by equilibrium statistical mechanics. This trapped-ion platform can be scaled to higher numbers of spins, where detailed modeling of MBL or prethermal behavior becomes impossible due to the complexity of representing such highly entangled quantum states.