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Quantum many-body scars: a new form of ergodicity breaking in a Rydberg-atom quantum simulator

DMITRY ABANIN, Perimeter Institute for Theoretical Physics

The thermodynamic description of many-particle systems rests on the assumption of ergodicity, the ability of a system to explore all allowed configurations in the phase space. Recent studies of many-body localization have revealed the existence of systems that strongly violate ergodicity in the presence of quenched disorder. Here, we demonstrate that ergodicity can be weakly broken by a different mechanism, arising from the presence of special eigenstates in the many-body spectrum that are reminiscent of quantum scars in chaotic non-interacting systems. In the single-particle case, quantum scars correspond to wave functions that concentrate in the vicinity of unstable periodic classical trajectories. We show that many-body scars appear in the Fibonacci chain, a model with a constrained local Hilbert space that has been recently experimentally realized in a Rydberg-atom quantum simulator. The quantum scarred eigenstates are embedded throughout the otherwise ergodic many-body spectrum, but lead to direct experimental signatures, as we show for periodic recurrences that reproduce those observed in the experiment. Our results suggest that scarred many-body bands give rise to a new universality class of quantum dynamics, opening up opportunities for the creation of novel states with long-lived coherence in systems that are now experimentally realizable.