Restoring thermalization in long-range quantum magnets with staggered magnetic fields

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Quantum systems with strong long-range interactions are thought to robustly resist thermalization because their energy spectra organize into a discrete number of multiplets. We show that this non-thermal behavior is surprisingly fragile to an experimentally ubiquitous perturbation: a staggered magnetic field. Using self-consistent mean-field theory and exact diagonalization, we reveal that the energy spectrum, while composed of discrete subspaces or multiplets, collectively forms a dense spectrum. For initial states at low to intermediate energies, the long-time average aligns with the microcanonical ensemble. However, for states in the middle of the spectrum the long-time average depends on the initial state due to quantum scar-like eigenstates localized at unstable points in classical phase space. Our results can be readily tested on a range of experimental platforms, including Rydberg atoms or optical cavities.

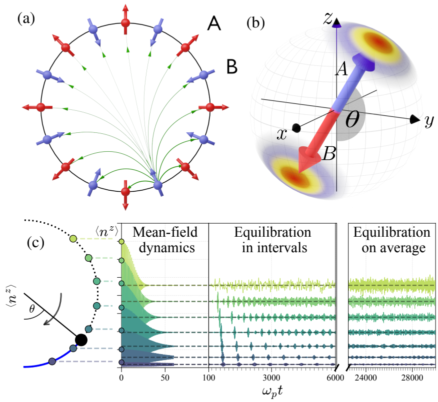

Fig. 1: Dynamics of a LR Heisenberg antiferromagnet.(a) Illustration of the system; a spin chain with two sublattices A (red) and B (blue) coupled via power-law interactions. (b) Mixed Néel initial states (angle θ, spread σ). (c) $\langle n^z \rangle$ shows pendulum-like oscillations, revivals, and long-time equilibration to the mircocanonical ensemble (dashed). Parameters: $J/h = 5$, $N = 500$, $\alpha = 0$, $\sigma = 10^{-2}$.

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