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Asymptotic quantum many-body scars

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We consider a quantum lattice spin model featuring exact quasiparticle towers of eigenstates with low entanglement at finite size, known as quantum many-body scars (QMBS). We show that the states in the neighboring part of the energy spectrum can be superposed to construct entire families of low-entanglement states whose energy variance decreases asymptotically to zero as the lattice size is increased. As a consequence, they have a relaxation time that diverges in the thermodynamic limit, and therefore exhibit the typical behavior of exact QMBS although they are not exact eigenstates of the Hamiltonian for any finite size.

We refer to such states as asymptotic QMBS. These states are orthogonal to any exact QMBS at any finite size, and their existence shows that the presence of an exact QMBS leaves important signatures of non-thermalness in the rest of the spectrum; therefore, QMBS-like phenomena can hide in what is typically considered the thermal part of the spectrum. We support our study using numerical simulations in the spin-1 XY model, a paradigmatic model for QMBS, and we conclude by presenting a weak perturbation of the model that destroys the exact QMBS while keeping the asymptotic QMBS.

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