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Title: Homogeneous Floquet time crystal from weak ergodicity breaking

Abstract: Recent works on the observation of discrete time-crystallinity throw up major puzzles on the necessity of localization for stabilizing such out-of-equilibrium phases. Motivated by these studies, we delve into a clean interacting Floquet system whose quasi-spectrum conforms to the ergodic Wigner-Dyson distribution, yet with an unexpectedly robust, long-lived time-crystalline dynamics in the absence of disorder or fine-tuning. We relate such behavior to a measure zero set of nonthermal Floquet eigenstates with long-range spatial correlations, which coexist with otherwise thermal states at near-infinite temperature and develop a high overlap with a family of translationally invariant, symmetry-broken initial conditions. This resembles the notion of “dynamical scars” that remain robustly localized throughout a thermalizing Floquet spectrum with fractured structure. We dub such a long-lived discrete time crystal formed in partially nonergodic systems, “scarred discrete time crystal” which is distinct by nature from those stabilized by either many-body localization or prethermalization mechanism.