The Floquet central spin model: A platform to realize eternal time crystals, entanglement steering, and multiparameter metrology

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We propose and characterize protocols to realize eternal discrete time crystals (DTCs) in the periodically driven central spin model. These eternal DTCs exhibit perfect periodic revivals of the initial state at a time mnT (where n>1 and {m,n}∈ℤ), when the Ising interaction strength, λ between the central spin and the satellite spins is tuned to certain values. The combination of perfect initial-state revival and time-translation-symmetry breaking leads to infinitely long-lived oscillations of the stroboscopic magnetization and the entanglement entropy in these DTCs even for a finite number of satellite spins. We analytically determine the conditions for the existence of these eternal DTCs and prove that the system exhibits eternal period-doubling oscillations (n=2) when λ=2π for an arbitrary number of satellite spins. Furthermore, we propose a protocol to realize eternal higher-order(HO)-DTCs (n>2) by tuning λ to π. Intriguingly, this protocol naturally steers the system through an entangled trajectory, thereby leading to the generation of maximally entangled Bell-cat states during the dynamical evolution of the HO-DTC. Finally, we demonstrate that these HO-DTCs can serve as a resource for Heisenberg-limited multiparameter sensing.