Realization of Two-dimensional Discrete Time Crystals with Anisotropic Heisenberg Coupling

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A discrete time crystal (DTC) is a non-equilibrium phase of matter characterized by spontaneous discrete time-translation symmetry breaking, offering a unique platform to explore fundamental questions in statistical physics. Specifically, it challenges the conventional expectation that driven quantum systems should thermalize, instead exhibiting robust macroscopic quantum coherence. While previous studies have primarily focused on one-dimensional Ising-like models due to computational constraints, the realization of DTCs in more general interaction settings remains an open problem.
In this work, we combine state-of-the-art tensor network methods with IBM's latest generation of quantum processors to investigate DTC behavior in a two-dimensional system governed by anisotropic Heisenberg interactions. Our results unveil a complex phase diagram encompassing spin-glass, ergodic, and time-crystalline phases, demonstrating how interaction anisotropy, initialization, and driving protocols influence DTC stability. By extending Floquet matter studies beyond simplified models, our findings provide new insights into the interplay between quantum coherence and emergent non-equilibrium thermodynamics, paving the way for future experimental realizations in solid-state and atomic platforms.