Qubit fractionalization and emergent Majorana liquid in the Floquet honeycomb code

Simon Trebst and Guo-Yi Zhu

Institute for Theoretical Physics, University of Cologne Germany

From the perspective of quantum many-body physics, the Floquet code of Hastings and Haah can be thought of as a measurement-only version of the Kitaev honeycomb model where a periodic sequence of two-qubit XX, YY, and ZZ measurements dynamically stabilizes a toric code state (a logical qubit). However, the most striking feature of the Kitaev model is its intrinsic fractionalization of quantum spins into an emergent gauge field and itinerant Majorana fermions that form a Dirac liquid. Here we demonstrate that by varying the measurement strength of the honeycomb Floquet code one can observe features akin to the finite-temperature physics of the Kitaev model. Introducing coherent errors by weakening the measurements we observe three consecutive stages that reveal qubit fractionalization (for weak measurements), the formation of a Majorana liquid (for intermediate measurement strength), and Majorana pairing together with gauge ordering (for strong measurements). Our analysis is based on hybrid Monte Carlo/tensor network simulations of Floquet codes in the presence of coherent noise that expose two crossover peaks and a mapping of the weak-measurement code to a finite temperature Kitaev-like problem subjected to random measurement records. For practical purposes, our analysis demonstrates that the Floquet code, in contrast to the toric code, does not immediately break down under weak measurements but exhibits a finite-size error threshold.