Anyon dynamics in field-driven phases of the Kitaev model

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The Kitaev model on a honeycomb lattice with bond-dependent Ising interactions offers an exactly solvable model of a quantum spin liquid (QSL) with gapped Z_2 fluxes and gapless linearly dispersing majorana fermions in the isotropic limit ($K_x = K_y = K_z$). We explore the phase diagram along two axes, an external magnetic field, h, applied out-of-plane of the honeycomb, and anisotropic interactions, K_z larger than the other two. For $K_z/K \gg 2$ and $h = 0$, the matter majorana fermions have the largest gap, and the system is described by a gapped Z_2 Toric code in which the Z_2 fluxes form the low energy bosonic Ising electric (e) and magnetic (m) charges along with their fermionic bound state $\epsilon = e \times m$. In this regime, we find that a small out-of-plane magnetic field creates ϵ fermions that disperse in fixed one-dimensional directions before the transition to a valence bond solid phase, providing a direct dynamical signature of low energy Z_2 Abelian flux excitations separated from the majorana sector. At lower K_z in the center of the Abelian phase, in a regime we dub the primordial fractionalized (PF) regime, the field generates a hybridization between the ϵ fermions and the majorana matter fermions, resulting in a ψ fermion. All the other phases in the field-anisotropy plane are naturally obtained from this primordial soup. We show that in the Z_2 Abelian phase, including the PF regime, the dynamical structure factors of local spin flip operators reveal distinct peaks that can be identified as arising from different anyonic excitations. We present in detail their signatures in energy and momentum and propose their identification by inelastic light scattering as “smoking gun” signatures of fractionalization in the QSL phase. Our analysis is based on calculations of susceptibilities, topological entanglement entropy, and excitation dynamics, obtained using exact diagonalization and density matrix renormalization group.