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Spontaneously Broken Non-Invertible Symmetries in Transverse-Field Ising Qudit Chains

Recent developments have revealed that symmetries need not form a group, but instead can be non-invertible. Here we use analytical arguments and numerical evidence to illuminate how spontaneous symmetry breaking of a non-invertible symmetry is similar yet distinct from ordinary symmetry breaking. We consider one-dimensional chains of group-valued qudits, whose local Hilbert space is spanned by elements of a finite group G (reducing to ordinary qubits when $G = Z_2$). We construct Ising-type transverse-field Hamiltonians with Rep(G) symmetry whose generators multiply according to the tensor product of irreducible representations (irreps) of the group G. For non-Abelian G, the symmetry is non-invertible. In the symmetry broken phase there is one ground state per irrep on a closed chain. The symmetry breaking can be detected by local order parameters but, unlike the invertible case, different ground states have distinct entanglement patterns. We show that for each irrep of dimension greater than one the corresponding ground state exhibits string order, entanglement spectrum degeneracies, and has gapless edge modes on an open chain – features usually associated with symmetry-protected topological order. Consequently, domain wall excitations behave as one-dimensional non-Abelian anyons with non-trivial internal Hilbert spaces and fusion rules. Our work identifies properties of non-invertible symmetry breaking that existing quantum hardware can probe.

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