

Topological quantum order: stability under local perturbations

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Quantum spin Hamiltonians exhibiting topological quantum order (TQO) have a remarkable property that their ground state degeneracy cannot be lifted by generic local perturbations. In addition, the spectral gap above the ground state does not close in a presence of such perturbations. This property is in sharp contrast with the behavior of classical spin Hamiltonians such as the 2D Ising model for which the ground state degeneracy is unstable in a presence of external magnetic field. We derive simple conditions that guarantee stability of the spectral gap and the ground state degeneracy under generic local perturbations. These conditions thus can be regarded as a rigorous definition of TQO. Our results apply to any quantum spin Hamiltonian that can be written as a sum of geometrically local commuting projectors on a D -dimensional lattice. This large class of Hamiltonians includes Levin-Wen string-net models and Kitaev's quantum double models. Our gap stability theorem implies that Hamiltonians with TQO can be engineered using perturbative gadgets with bounded-strength interactions. We discuss how our techniques can be used to analyze stability of quantum memories at the zero temperature.