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Lattice quantum codes and exotic topological phases of matter

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Is it possible to build a "hard disk drive" for quantum information? The quantum coherence time in a usual thermal system is fundamentally limited by the inverse Boltzmann factor $\exp[\Delta/kT]$, where Δ is the energy scale of the system. This limitation is not enhanced even with a conventional topologically ordered system in three or lower dimensions. Here, a new three-dimensional spin model is presented that shows a qualitatively different behavior. It can be viewed as a quantum error correcting code, and is thus exactly solvable. The ground states are locally indistinguishable, for which it may be called topologically ordered. However, the model only admits immobile pointlike excitations, and the immobility is not affected by small perturbations of the Hamiltonian. The degeneracy of the ground state, though also insensitive to perturbations, is a complicated number-theoretic function of the system size. Under real-space renormalization group transformations, the system bifurcates into multiple noninteracting copies of itself. Similarities and differences of the model in comparison to Wegner's Ising gauge theory will be explained. When quantum information is encoded into a ground state of this model and subjected to thermal errors, the errors remain easily correctable for a long time without any active intervention, because a macroscopic energy barrier due to the immobility of excitations keeps the errors well localized. As a result, stored quantum information can be retrieved faithfully for a memory time $\exp[(\Delta/kT)^2]$.