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Identifying Phases of Matter that are Universal for Quantum Computation

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Abstract

A recent breakthrough in quantum computing has been the realization that quantum computation can proceed solely through single-qubit measurements on an appropriate quantum state - for example, the ground state of an interacting many-body system. It would be unfortunate, however, if the usefulness of a ground state for quantum computation was critically dependent on the details of the system's Hamiltonian; a much more powerful result would be the existence of a robust ordered phase which is characterized by the ability to perform measurement-based quantum computation (MBQC). To identify such phases, we propose to use nonlocal correlation functions that quantify the fidelity of quantum gates performed between distant qubits. We investigate a simple spin-lattice system based on the cluster-state model for MBQC, and demonstrate that it possesses a zero temperature phase transition between a disordered phase and an ordered "cluster phase" in which it is possible to perform a universal set of quantum gates.