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Information Processing in Quantum Thermodynamic Systems: an Autonomous Hamiltonian Approach

Extending the quantum formulation of [Phys. Rev. X 3, 041003 (2013)] to a more general setting for studying the thermodynamics of information processing including initial correlations, we generalize the second law of thermodynamics to account for information processing in such autonomous systems. We consider a composite quantum system consisting of a principal system, heat bath, memory, and work source, and adopt an autonomous Hamiltonian framework. We derive
constraints on the total Hamiltonian that ensure the work source to act as a catalyst preserving its original randomness, namely that the total unitary evolution must have a unitary partial transpose. We show that this requirement is equivalent to the commutativity of operators acting on the joint system of the principal system, bath, and memory, which underlies the Hamiltonian structure. Next, we generalize the quantum speed limit for the joint dynamics of system and memory to the quantum thermodynamic speed limit, from which we obtain a dynamical version of Landauer's bound. More importantly, we also interpret this quantum thermodynamic speed limit in the context of quantum hypothesis testing.

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