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Relaxation vs. adiabatic quantum steady state preparation: which wins?

Adiabatic preparation of the ground states of many-body Hamiltonians in the closed system limit is at the heart of adiabatic quantum computation, but in reality systems are always open. This motivates a natural comparison between, on the one hand, adiabatic preparation of steady states of Lindbladian generators and, on the other hand, relaxation towards the same steady states subject to the final Lindbladian of the adiabatic process. In this work we thus adopt the perspective that the goal is the most efficient possible preparation of such steady states, rather than ground states. Using known rigorous bounds for the open-system adiabatic theorem and for mixing times, we are then led to a disturbing conclusion that at first appears to doom efforts to build physical quantum annealers: relaxation seems to always converge faster than adiabatic preparation. However, by carefully estimating the adiabatic preparation time for Lindbladians describing thermalization in the low temperature limit, we show that there is, after all, room for an adiabatic speedup over relaxation. To test the analytically derived bounds for the adiabatic preparation time and the relaxation time, we numerically study three models: a dissipative quasi-free fermionic chain, a single qubit coupled to a thermal bath, and the "spike" problem of n qubits coupled to a thermal bath. Via these models we find that the answer to the "which wins" question depends for each model on the temperature and the system-bath coupling strength. In the case of the "spike" problem we find that relaxation during the adiabatic evolution plays an important role in ensuring a speedup over the final-time relaxation procedure. Thus, relaxation-assisted adiabatic preparation can be more efficient than both pure adiabatic evolution and pure relaxation.