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Classical simulation of short-time quantum dynamics

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Recent progress in the development of quantum technologies has enabled the direct investigation of dynamics of increasingly complex quantum many-body systems. This motivates the study of the complexity of classical algorithms for this problem in order to benchmark quantum simulators and to delineate the regime of quantum advantage. Here we present classical algorithms for approximating the dynamics of local observables and nonlocal quantities such as the Loschmidt echo, where the evolution is governed by a local Hamiltonian. For short times, their computational cost scales polynomially with the system size and the inverse of the approximation error. In the case of local observables, the proposed algorithm has a better dependence on the approximation error than algorithms based on the Lieb–Robinson bound. Our results use cluster expansion techniques adapted to the dynamical setting, for which we give a novel proof of their convergence. This has important physical consequences besides our efficient algorithms. In particular, we establish a novel quantum speed limit, a bound on dynamical phase transitions, and a concentration bound for product states evolved for short times.

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