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Robustness of digital quantum simulation

Abstract: Quantum simulators offer an exciting perspective to solve quantum many-body problems. A particularly promising path is digital quantum simulation (DQS), where the desired many-body Hamiltonian is Trotterized, i.e., broken down into discrete, elementary gates. This procedure allows for the synthetization of practically arbitrary Hamiltonians, but comes at a prize: the discretization of time induces an intrinsic source of Trotter errors. Common knowledge is that these errors unavoidably increase with simulated time as well as system size.
In this talk, I argue that this is true only if one is interested in the correctness of the full time-evolution operator. If, however, one is interested in local observables, one can control Trotter errors to perturbative precision even at extremely long times. A sharp quantum-chaos threshold separates this perturbative regime from a regime where Trotter errors proliferate uncontrollably. I will illustrate the discussion with a particularly exciting target, the quantum simulation of lattice gauge theories. Our findings are based on exact numerics as well as on connecting DQS to periodically driven systems, energy localization, and quantum chaos, and they show that DQS is dramatically more robust than previously thought.