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**Simulating spin-boson models with matrix product states**[1]

MICHAEL WALL, ARGHAVAN SAFAVI-NAINI, ANA MARIA REY, JILA — The global coupling of few-level quantum systems ("spins") to a discrete set of bosonic modes is a key ingredient for many applications in quantum science, including large-scale entanglement generation, quantum simulation of the dynamics of long-range interacting spin models, and hybrid platforms for force and spin sensing. In many situations, the bosons are integrated out, leading to effective long-range interactions between the spins; however, strong spin-boson coupling invalidates this approach, and spin-boson entanglement degrades the fidelity of quantum simulation of spin models. We present a general numerical method for treating the out-of-equilibrium dynamics of spin-boson systems based on matrix product states. While most efficient for weak coupling or small numbers of boson modes, our method applies for any spatial and operator dependence of the spin-boson coupling. In addition, our approach allows straightforward computation of many quantities of interest, such as the full counting statistics of collective spin measurements and quantum simulation infidelity due to spin-boson entanglement. We apply our method to ongoing trapped ion quantum simulator experiments in analytically intractable regimes.

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