Variational quantum simulation of frustrated quantum magnets in the thermodynamic limit

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Variational quantum algorithms (VQA), generically characterized by a feedback loop between a quantum device and a classical optimizer, are at the center of current research for their potentiality in providing first useful applications of noisy intermediate scale quantum (NISQ) devices in problems ranging machine learning and quantum simulation. However, various roadblocks have been identified in their optimization, potentially hindering any applicability of VQA. Quantum simulation of two-dimensional (2D) frustrated quantum magnets offers a natural arena for benchmark and development of VQA, for they pose a challenge to state-of-the-art numerical techniques and at the same time host a plethora of phases with implications for quantum computation. In this talk, I will present a VQA to simulate 2D frustrated quantum magnets in the thermodynamic limit. Building upon hierarchical mean-field theory (HMFT) and the cluster-Gutzwiller ansatz, a parameterized quantum circuit respecting square superconducting chip connectivities provides the wave function of the cluster, while information of the infinite lattice is provided through a self-consistent mean-field embedding. After reviewing some long-standing questions in frustrated quantum magnetism and the basics of HMFT, I will provide benchmark numerical simulations of the *quantum-assisted* HMFT (Q-HMFT) on the paradigmatic J1-J2 Heisenberg antiferromagnet on the square lattice showing that the convergence of the algorithm is pushed by the onset of long-range order, opening a promising route for quantum simulation of 2D quantum magnets and their quantum phase transitions to valence bond solid phases with current superconducting circuit technology. I will end by discussing different applications and extensions.

References

[1] Daniel Huerga, Quantum 6, 874 (2022)

Figures

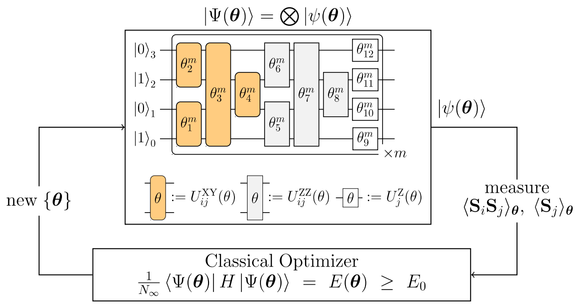

Figure 1: Algorithmic flow of Q-HMFT for a 4-qubit cluster-Gutzwiller.