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Quantifying the efficiency of state preparation via quantum variational eigensolvers

Recently, there has been much interest in the efficient preparation of complex quantum states using low-depth quantum circuits, such as Quantum Approximate Optimization Algorithm (QAOA). While it has been numerically shown that such algorithms prepare certain correlated states of quantum spins with surprising accuracy, a systematic way of quantifying the efficiency of QAOA in general classes of models has been lacking. Here, we propose that the success of QAOA in preparing ordered states is related to the interaction distance of the target state, which measures how close that state is to the manifold of all Gaussian states in an arbitrary basis of single-particle modes. We numerically verify this for the ground state of the quantum Ising model with arbitrary transverse and longitudinal field strengths, a canonical example of a non-integrable model. Our results suggest that the structure of the entanglement spectrum, as witnessed by the interaction distance, correlates with the success of QAOA state preparation. We conclude that QAOA typically finds a solution that perturbs around the closest free-fermion state.

Presenter: Mr MATOS, Gabriel (University of Leeds)

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