Critical Behaviour and Closing Gap Issue Within Noisy Variational State Preparation

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Abstract

Preparation of quantum state in form of a variational quantum circuit plays a crucial role in quantum computing applications such as quantum chemistry. Quality (fidelity) of the resulting state depends on, in addition to circuit architecture, the number of circuit shots N_S used on each iteration of stochastic gradient descent. In this work, within simulation of two-dimensional frustrated quantum magnets, we observe that fidelity shows critical temperature-like behavior in N_S, giving rise to the notion of *critical effective temperature*. Below this critical temperature, we observe that the resource demand of the variational optimization grows as $\sim 1/\Delta^2$ with the system gap Δ, reminding of the adiabatic theorem annealing time bound. We analyze the effect of this $N_S \sim 1/\Delta^2$ dependence on the possibility of large-scale simulations of frustrated magnets. We provide a symmetry-based approach allowing in some cases to significantly reduce the simulation costs of VQE applied to frustrated magnets.

Figures

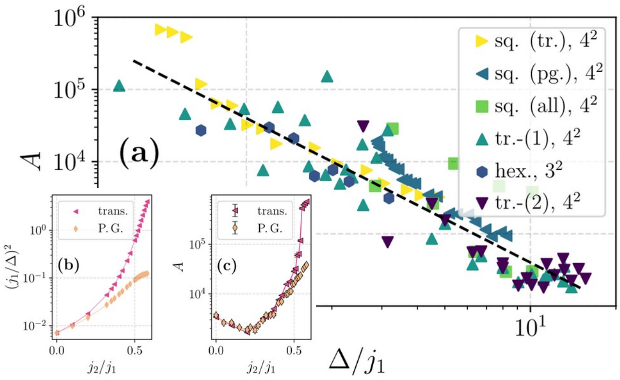

Figure 1: Resources demand A (required number of circuit shots) to reach a fixed overlap with the ground state, simulated within gradient descent VQE at various frustrated 2d magnets as the function of inverse gap. The $1/\Delta^2$ fit is shown. The inset shows that symmetry projection can vary the system gap, resulting in significant reduction of A (translational symmetry as compared to point group symmetry).

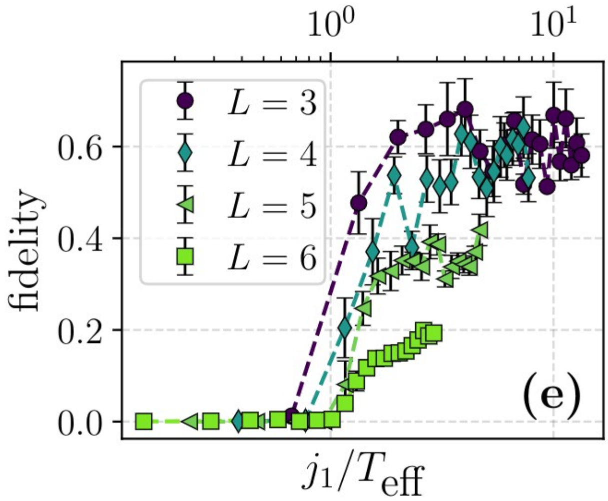

Figure 2: Fidelity as the function of number of samples (inverse effective temperature) shows critical behaviour. The critical temperature depends on the system size and is being extrapolated to thermodynamic limit.