Robustness of dissipative quantum algorithms against noise-induced barren plateaus

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Noise is a major hurdle towards practical applications of quantum computing. In parameterized quantum and circuits quantum machine learning, it can lead to noise induced barren plateaus, which limits the depth and therefore system size that can be considered. Specifically, the expectation value of the cost function becomes exponentially concentrated at a noise-induced fixed point and the gradients are exponentially suppressed in the depth of the algorithm [1]. Dissipative algorithms that cool towards many body ground states offer a potential solution [2]. These algorithms leverage nonunitary dynamics to achieve desirable properties, such as stabilizing these states for times beyond a system's coherence time [3]. By parameterizing these algorithms, we unlock a multitude of applications that go beyond quantum simulation. We derive an exact expression for their steady state and demonstrate that there are problems where a unitary learner suffers from noise-induced barren plateaus, while a dissipative learner can avoid them. We verify this analytic result with simulations (see Fig. 1), providing empirical support for our theoretical findings. Dissipative evolution can reduce the entropy of a quantum system, a crucial property in the present pre-fault-tolerant era where errors increase entropy. We demonstrate how this property can be harnessed algorithmically.

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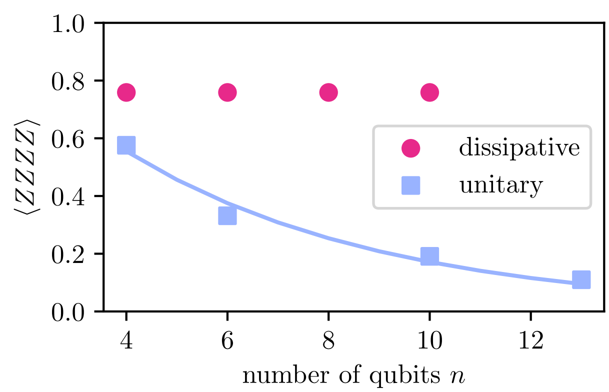

FIG. 1: **Absence of noise induced barren plateaus in dissipative learners** We plot the expectation value of one pauli string after training against the number of qubits. The problem we consider the preparation of Toric code ground states. A unitary circuit requires a depth that scales with $\sqrt{n}$ while depth of individual jumps of the dissipative algorithm is constant. Consequently, the expectation value of the unitary learner exponentially approaches the noise induced fixed point in the number of qubits while the expectation value of the dissipative learner is constant.