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Estimates of loss function concentration in noisy parametrized quantum circuits

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See attached pdf abstract.

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Short summary

Variational quantum computing offers a powerful framework with applications across diverse fields such as quantum chemistry, machine learning, and optimization. However, its scalability is hindered by the exponential concentration of the loss function, known as the barren plateau problem. While significant progress has been made in understanding barren plateaus in unitary and noisy circuits independently, their combined effects remain poorly understood due to limitations in standard Lie algebraic methods. In this work, we introduce a new analytical formulation based on non-negative matrix theory that enables precise calculation of the variance in deep noisy circuits, unveiling the complex interplay between unitary circuits and noise. In particular, we show the emergence of a noise-induced absorption mechanism, a phenomenon that cannot arise in the purely reversible context of unitary quantum computing. Nevertheless, general lower bounds on the variance of deep circuits can still be established, constraining arbitrary circuits to effectively mimic the behaviour of shallow ones. When applied in the noisy setting, this allows us to establish a deep connection between the noise resilience of parameterized circuits and the potential to enhance their expressive power through smart initialization strategies.

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