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Role of nonstabilizerness in quantum optimization

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Quantum optimization has emerged as a promising approach for tackling complicated classical optimization problems using quantum devices. However, the extent to which such algorithms harness genuine quantum resources and the role of these resources in their success remain open questions.

In this work, we investigate the resource requirements of the Quantum Approximate Optimization Algorithm (QAOA) through the lens of the resource theory of nonstabilizerness. We demonstrate that the nonstabilizerness in QAOA increases with circuit depth before it reaches a maximum, to fall again during the approach to the final solution state—creating a barrier that limits the algorithm’s capability for shallow circuits. We find curves corresponding to different depths to collapse under a simple rescaling, and we reveal a nontrivial relationship between the final nonstabilizerness and the success probability.

Finally, we identify a similar nonstabilizerness barrier also in adiabatic quantum annealing. Our results provide deeper insights into how quantum resources influence quantum optimization.

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