Complexity-driven ground state estimation of quantum many-body systems

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Understanding which quantum states can be efficiently represented and simulated classically is essential for advancing both fundamental physics and the development of quantum technologies. In this work, we want to leverage knowledge about the complexity of quantum many-body systems to estimate ground states using an efficient balance between quantum and classical resources [1].

We characterize the quantum complexity of ground states through entanglement (e.g., n-tangles), non-stabilizerness (e.g., Stabilizer Rényi entropies, non-local magic), and non-Gaussianity (e.g., fermionic anti-flatness) to illuminate how quantum resources behave throughout the system.

All these measures are not only interesting to improve quantum-classical workflows but can be connected to the phase diagram of the Agassi model that we use as a benchmark. The three different phases (spherical, deformed, and superfluid) make the Agassi model interesting for various areas of physics such as Nuclear and Subnuclear Physics, Condensed Matter Physics and Strongly Correlated Electronic Systems.

Finally, using the techniques developed in [2] we show that (superpositions of) stabilizer ground states describe the ground state of the Agassi model with high fidelity. This allows more efficient simulations of quantum systems by exploiting knowledge about their the quantum complexity, and constitutes a step towards exploring more complex systems.

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[2] Caroline E. P. Robin, Phys. Rev. A **112**, 052408 (2025).