Exploring Long-Range Correlated Fermi-Hubbard Models on IBM Heron v2 using the SqDRIFT Algorithm

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Recent advancements in hybrid quantum-classical workflows have demonstrated that pre-fault tolerant quantum devices can be used to simulate electronic models that often contain onsite correlations [1-3]. In contrast, models with extended long-range correlations have not been simulated extensively with these workflows, as some parameter regimes require a large number of Slater determinants to describe important eigenstates. In this work we investigate a class of these models, the “extended” Fermi–Hubbard model, for two-dimensional clusters using IBM's Heron v2 quantum computer (IBM_BasqueCountry). To address the difficulty in simulating this model, we leverage the state-of-the-art SqDRIFT algorithm [4], which combines sample-based Krylov quantum diagonalization (SKQD) [5] with the qDRIFT randomized compilation of the Hamiltonian propagator [6]. We compare the experimentally obtained ground-state and excited state spectra to numerically exact classical simulations, while also evaluating the roles of system size, device noise, and circuit depth on the algorithm's accuracy. These results provide a first demonstration of the SqDRIFT algorithm applied to strongly correlated lattice models with long-range interactions, extending its viability for studying complex quantum many-body physics in the pre-fault-tolerant quantum computing era.

References

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