# Quantum subspace expansion in the presence of hardware noise

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Finding ground state energies on current quantum processing units (QPUs) using algorithms like the variational quantum eigensolver (VQE) continues to pose challenges. Hardware noise severely affects both expressivity and trainability of parametrized quantum circuits, limiting them to shallow depths in practice. Here, we demonstrate that both issues can be addressed by synergistically integrating VQE with a quantum subspace expansion, allowing for an optimal balance between quantum and classical computing capabilities and costs. We perform a systematic benchmark analysis of the iterative quantum-assisted eigensolver of [1] in the presence of hardware noise. We determine ground state energies of 1D and 2D mixed-field Ising spin models (MFIM) on noisy simulators and on the IBM QPUs ibmq_quito (5 qubits) and ibmq_guadalupe (16 qubits). To maximize accuracy, we propose a suitable criterion to select the subspace basis vectors according to the trace of the noisy overlap matrix. Finally, we show how to systematically approach the exact solution by performing controlled quantum error mitigation based on probabilistic error reduction (PER) on the noisy backend fake_guadalupe.

## Figures

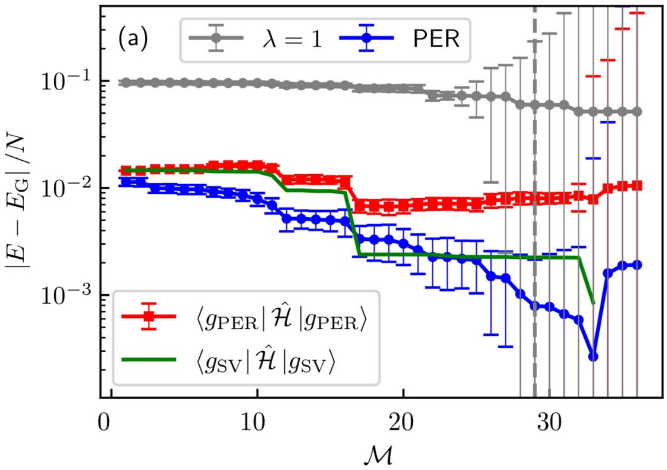


**Figure 1:** Paired iterative quantum-assisted eigensolver calculations on fake_guadalupe using PER quantum error mitigation. Energy error per site as a function of subspace dimension for a 16-site MFIM.

## References

[1] K. Bharti and T. Haug, Phys. Rev. A 104, L050401 (2021)