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Self-Verifying Variational Quantum Simulation of Lattice Models

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Hybrid classical-quantum algorithms aim at variationally solving optimization problems, using a feedback loop between a classical computer and a quantum co-processor, while benefitting from quantum resources. Here we present experiments demonstrating self-verifying, hybrid, variational quantum simulation of lattice models in condensed matter and high-energy physics. Contrary to analog quantum simulation, this approach forgoes the requirement of realising the targeted Hamiltonian directly in the laboratory, thus allowing the study of a wide variety of previously intractable target models. Our quantum co-processor is a programmable, trapped-ion analog quantum simulator with up to 20 qubits, capable of generating families of entangled trial states respecting symmetries of the target Hamiltonian. We determine ground states, energy gaps and, by measuring variances of the Schwinger Hamiltonian, we provide algorithmic error bars for energies, thus addressing the long-standing challenge of verifying quantum simulation.