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# Efficient calculation of Green's functions on quantum computers via simultaneous circuit perturbation

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Understanding the dynamical properties of quantum many-body systems is a pivotal question in virtually all areas of modern physical sciences, including condensed matter, high-energy physics, and quantum chemistry. However, because of the often strongly correlated nature of the relevant models and the associated rapid growth of entanglement during time evolution, their study remains challenging at large scale. In the last decade, quantum computers have emerged as a promising computational paradigm to address this class of problems, and recent demonstrations of quantum simulations at the quantum utility scale have opened the way to the use of digital quantum information processing platforms as concrete, state-of-the-art research tools for fundamental physics.

In this work, we focus on the computation of the retarded Green's function (RGF). These functions naturally arise in linear response theory (LRT), where they help derive essential properties like conductivity and magnetization, and are closely related to two-time dynamical correlations (DCs). In a $N$-site lattice spin model, ground state DCs are represented as $\mathcal{C}(r,r',t,t') = \langle o_r(t)o_{r'}(t')\rangle = \sum_p \langle 0|o_r(t)|p\rangle\langle p|o_{r'}(t')|0\rangle e^{-i\mathcal{E}_p t}$. Here, $o_r$ is a local observable (e.g., a spin component represented by a Pauli matrix) on the lattice site at position $r$ and $|p\rangle$ are excited Hamiltonian eigenstates with energies $\mathcal{E}_p$.

A typical method for extracting DCs on a quantum computer leverages the so-called Hadamard test, an ancilla-based algorithm. However, its inherent non-local nature restricts its applicability on large-scale devices with limited qubit-qubit connectivity. Here, we propose a method to overcome these restraints by leveraging randomized quantum circuit perturbations within a linear response-inspired framework.

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## Short summary

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