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Quantum Algorithms for Efficient Classical Plasma Simulation

ALEXANDER ENGEL, GRAEME SMITH, SCOTT PARKER, University of Colorado, Boulder — In the field of quantum computing, algorithms are being developed that offer a variety of speedups over their classical counterparts. Could future quantum computers be applied to reduce the costs of kinetic plasma simulations? We investigate this question by developing a quantum algorithm for a very simple plasma problem: linear Landau damping. This algorithm is designed to be run on a universal, error-corrected quantum computer, and is worked out in detail and verified numerically. While classical simulation of the Vlasov-Poisson system has costs that scale as $\mathcal{O}(\mathcal{N}\mathcal{T})$ for a phase space grid with N grid points and simulation time T, our quantum algorithm scales as $\mathcal{O}(\sqrt{\wr\updownarrow\dagger\updownarrow\wr\}}(\mathcal{N})\mathcal{T}/\delta)$ where δ is the measurement error. We find that a quantum computer could efficiently handle a high resolution, six-dimensional phase-space grid, but the $1/\delta$ cost factor to extract a result remains a difficulty. Since we only handle linear, damped cases, this is not a general algorithm for present day kinetic plasma simulation, but by working out the details we showcase the capabilities and limitations of quantum computers, generally and in the specific context of classical plasma physics simulation.

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