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Onset of hydrodynamics in a strongly coupled system based on quantum many-body calculation

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Onset of hydrodynamics in the hot medium created in relativistic heavy-ion collisions is a crucial theoretical question. Addressing this problem in a first-principle manner, requires a **real-time, non-perturbative simulation of a large scale quantum system**, as hydrodynamic behavior emerges only when approaching the continuum limit. The exponentially large Hilbert space of quantum states prevents an exact simulation on classical hardwares. To overcome such a difficulty, we perform such a simulation using the Tensor Network method, which enables simulations of a reduced representation space of large scale quantum many-body systems by keeping only the most essential quantum states contributing to macroscopic quantities.

We focus on the massive Schwinger model, a low-dimension analog of quantum chromodynamics (QCD), as it shares the important properties such as confinement and chiral symmetry breaking. Starting from an initial quantum state that mimics hard particle collisions, we *observe the onset of hydrodynamic behavior* that is **consistent with the Bjorken-flow** in all hydrodynamic degrees of freedom: *energy density, fluid velocity, and bulk pressure.* The time scale for the onset of hydrodynamics is found to be consistent with the thermalization time of the quantum distribution function. Both time scales are of the same order as the hydrodynamization time determined by fitting the experimental data, upon a physical matching that extrapolates the 1+1 dimensional Schwinger model to the 3+1 dimension QCD.

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