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Quantum thermalization of Quark Gluon Plasma

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Thermalization of the quark gluon plasma (QGP) created in relativistic heavy-ion collisions is a crucial theoretical question in understanding the onset of hydrodynamics, and in a broad sense, a key step to the exploration of thermalization in quantum many body systems. Addressing this problem theoretically, in a first principle manner, requires a real-time, non-perturbative method. To this end, we carry out a fully quantum simulation on a classical hardware, of a massive Schwinger model, which well mimics QCD as it shares the important properties such as confinement and chiral symmetry breaking. We focus on the real-time evolution of the Wigner function,

which is the Wigner—Weyl transformation of the gauge-invariant two-point correlation function and it serves as the quantum analogy of the quark distribution function in phase space.

Starting from a non-equilibrium initial state, the real time evolution of the Wigner functions, as well as the entanglement entropy, both demonstrate that thermalization of the quantum system is approachable. In particular, relaxation to the thermalized state depends on coupling strength, in the presence of quantum fluctuations. The system tends to thermalize in the strong-coupling case, but not the weak-coupling ones. We also study the connection of the Wigner function thermalization to the Eigenstate Thermalization (ETH). The ETH is a well-known postulation that explains the thermalization of observables in isolated quantum many-body systems without processing quantum ergodicity. The satisfaction of ETH sheds light on the rapid thermalization of QGP created in heavy-ion collisions.

We also find the weak eigenstate thermalization hypothesis corresponding to the choice of difference initial quantum state. It indicates the relationship between the thermalization behavior and discrete symmetry like parity based on the quantum many body scar states reflecting the symmetry of the quantum system.

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