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Far-off-equilibrium early-stage dynamics in high-energy nuclear collisions

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We explore the far-off-equilibrium aspects of the (1+1)-dimensional early-stage evolution of a weakly-coupled quark-gluon plasma using hydrodynamics and kinetic theory. For a large set of far-off-equilibrium initial conditions we observe that the macroscopic evolution appears to violate simple rules based on the second law of thermodynamics. We provide an in-depth microscopic understanding of this apparently anomalous macroscopic phenomenon in terms of the novel concept of *viscous cooling* and establish its thermodynamic consistency. We use Boltzmann's H-function to formulate 'maximum-entropy hydrodynamics', a far-off-equilibrium macroscopic theory that can describe both free-streaming and near-equilibrium regimes of quark-gluon plasma in a single framework. Unlike traditional hydrodynamic theories but conceptually similar to anisotropic hydrodynamics which it generalizes and with which we compare, this formulation incorporates contributions to all orders in shear and bulk inverse Reynolds numbers, allowing it to handle large dissipative fluxes that characterize the early evolution stage in heavy-ion collisions. By considering flow profiles relevant for nuclear collisions at very high energies, we demonstrate that 'maximum-entropy hydrodynamics' provides excellent agreement with underlying kinetic theory throughout the fluid's evolution, especially in out-of-equilibrium regimes where traditional hydrodynamics breaks down.

Category

Theory

Collaboration (if applicable)

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