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Thermalization and hydrodynamics in Bjorken and Gubser flows

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Rapid and strongly anisotropic expansion throughout its evolution keeps the hot and dense medium created in relativistic heavy-ion collisions from ever reaching a state of local momentum isotropy and thermal equilibrium. Still, hydrodynamic descriptions of heavy-ion collisions are phenomenologically very successful. To elucidate the origin of this success we explore exactly solvable situations where the microscopic dynamics is described by the Boltzmann equation, and compare the exact solution with various hydrodynamic approximations obtained from the Boltzmann equation using different expansion schemes. Specifically, we study the performance of equations derived from a third-order Chapman-Enskog expansion and in the frameworks of second-order anisotropic and viscous hydrodynamics in comparison to the exact solution of the Boltzmann equation for Bjorken and Gubser flows. Systems with Bjorken flow approach an asymptotic state of local thermal equilibrium whereas in Gubser flow the expansion is so strong that the asymptotic state is free-streaming. Anisotropic hydrodynamics can be understood as a form of resummed hydrodynamics that includes terms of all orders in a gradient or Chapman-Enskog expansion. We study the evolution of the longitudinal-transverse pressure anisotropy, the shear stress and the rate of entropy production and show that for all three observables second-order anisotropic hydrodynamics in the P_L-matching scheme yields the best agreement with the exact solution of the Boltzmann equation, for both types of flows. We also show that the relatively largest discrepancies between the approximate hydrodynamic and exact kinetic solutions are observed for the entropy: the rate of entropy productions appears to be more strongly affected by couplings to rapidly evolving non-hydrodynamic modes than the hydrodynamic moments of the distribution function that make up the energy-momentum tensor. Phenomenological implications of these findings will be discussed.

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