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Viscous hydrodynamics for systems undergoing strongly anisotropic expansion

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The collective expansion in relativistic heavy-ion collisions is initially highly anisotropic. Due to viscosity, this leads to strongly deformed local momentum distributions which invalidates the standard viscous hydrodynamic expansion around a local equilibrium distribution, causing a breakdown of viscous fluid dynamics à la Israel and Stewart at early times. We have developed an improved formulation of viscous hydrodynamics [1] that is based on an expansion around a spheroidally deformed local momentum distribution. A spheroidal local momentum distribution leads to the "anisotropic hydrodynamics"developed earlier by Martinez and Strickland, which accounts non-perturbatively for the resulting large early-time anisotropy between the longitudinal and transverse pressures. By allowing in our new treatment for additional small deviations of the local momentum distribution from spheroidal symmetry, we arrive at a complete formulation of second-order viscous hydrodynamics in which the large longitudinal-transverse momentum anisotropy is treated non-perturbatively à la Martinez and Strickland while the smaller remaining viscous stress components are treated perturbatively à la Israel and Stewart. We perform a test of the approach for a system undergoing boost-invariant longitudinal expansion without transverse expansion which maximizes the longitudinal-transverse pressure anisotropy. For this system the Boltzmann equation can be solved exactly in the relaxation-time approximation, allowing for a quantitative test of effective macroscopic hydrodynamic theories. We find that the viscous anisotropic hydrodynamic framework ("vaHydro") significantly outperforms all other available hydrodynamic descriptions, for both small and large values of the shear viscosity eta/s. We expect vaHydro to provide a superior description also after including transverse expansion and to allow for an earlier matching of pre-equilibrium dynamics to hydrodynamics, due to the superior ability of vaHydro to handle the large differences in longitudinal and transverse expansion rates at early times.
[1] D. Bazow, U. Heinz, M. Strickland, arXiv:1311.6720, Phys. Rev. C, in press.

Author: Mr BAZOW, Dennis (The Ohio State University)

Co-author: Prof. HEINZ, Ulrich (The Ohio State University)

Presenter: Mr BAZOW, Dennis (The Ohio State University)