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Analytical solutions and attractors of relativistic viscous hydrodynamics for Bjorken flow

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We consider causal higher order theories of relativistic viscous hydrodynamics in the case of one-dimensional boost-invariant expansion and study the associated dynamical attractor. We obtain the evolution equations for inverse Reynolds number as a function of inverse Knudsen number. The solutions of these equations exhibit attractor behavior which we analyze in the context of Lyapunov exponents from several different techniques. We also compare attractors of second-order Muller-Israel-Stewart (MIS) theory, transient DNMR theory, third-order theory and exact solution of Boltzmann equation in the relaxation-time approximation. We demonstrate that the third-order theory provides a better approximation to the exact kinetic theory attractor compared to MIS and DNMR theories. Further, we find analytical solutions for these higher-order theories by assuming different forms of shear relaxation time and use these solutions to study the analytical attractors. Finally, we propose a new way to characterize and uniquely determine the hydrodynamic attractors, as well as the Lyapunov exponents, by studying the universal behavior of these solutions at small as well as large Knudsen numbers.

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