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Causal hydrodynamic fluctuation in Bjorken expansion

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We investigate effects of causal hydrodynamic fluctuation on dynamics of the quark gluon plasma (QGP) in Bjorken expansion in high-energy nuclear collisions. The space-time evolution of the QGP can be well described by relativistic hydrodynamics. In the recent hydrodynamic analyses, effects of event-by-event (e-by-e) initial fluctuation on final flow observables have been focused. Moreover, it is hotly debated whether the same hydrodynamic models can be applicable even in small systems such as p-p, p-A, and peripheral A-A collisions.

In this study, we focus on thermal fluctuation during hydrodynamic evolution which must be also important on an e-by-e basis of hydrodynamic description, in particular, in small systems.
We first introduce causal hydrodynamic fluctuation, namely the thermal noises arising during the hydrodynamic evolution, into the boost invariant Bjorken expansion. We next perform hydrodynamic simulations of the Bjorken model with hydrodynamic fluctuation on an e-by-e basis.

We find the final entropy fluctuates around the mean value even if the initial condition is fixed in a macroscopic sense. We also find the entropy can temporally decreases during the time evolution, which is allowed by the fluctuation theorem in non-equilibrium statistical physics. Fluctuation of entropy results in multiplicity fluctuation as an observable. Through the fluctuation-dissipation relation, hydrodynamic fluctuation is intimately related with dissipation. Thus final multiplicity fluctuation contains transport properties of the QGP. The fluctuation effect would be significant in small system such as p-p, p-A and peripheral A-A collisions. Therefore we may have a chance to constrain the transport properties in such small systems.

We further discuss rapidity dependent hydrodynamic fluctuation on top of boost-invariant Bjorken expansion to see whether long-range rapidity correlation can be contaminated by hydrodynamic fluctuations.

Primary authors: NAGAI, Kenichi (Sophia university); HIRANO, Tetsufumi (Sophia Univ)

Co-authors: MURASE, Koichi (The University of Tokyo); KURITA, Ryuichi (Univ. of Tokyo)

Presenter: NAGAI, Kenichi (Sophia university)

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