Contribution ID: **305** Type: **Poster**

Dynamics of causal hydrodynamic fluctuations in an expanding system

Saturday 9 September 2023 11:16 (5 minutes)

Nowadays, relativistic dissipative hydrodynamics including effects of finite viscosities is commonly used to extract transport properties of the quark gluon plasma (QGP), such as shear viscosity and bulk viscosity, from experimental data. However, according to the fluctuation-dissipation relation (FDR) in non-equilibrium statistical physics, fluctuations and dissipation are always accompanied with each other. Since phenomena induced by the hydrodynamic fluctuations, namely, thermal fluctuations associated with the viscosities, include the information of transport coefficients through FDR, these provide a multidimensional analysis of transport properties. Therefore, hydrodynamic fluctuations must be incorporated in the dynamical framework of relativistic heavy ion collisions. This could open up a new way of diagnosing the QGP properties precisely.

We derive equations of motion (EoM) of hydrodynamic fluctuations by considering the perturbative expansion of energy-momentum tensor around the Bjorken's boost invariant solution [1]. These EoMs are derived without any specific forms of constitutive equations contrary to a previous study in which constitutive equations from the first order dissipative hydrodynamics are assumed [2]. Therefore, this framework enables us to employ any kinds of constitutive equations at the second order dissipative hydrodynamics which satisfy the causality. This is the most precise framework in one-dimensional expanding system so far. With this framework, we describe the dynamics of (1+1)-dimensional causal hydrodynamic fluctuations and observe fluctuations of energy density are frozen in the early stage. It indicates that the distribution of energy density carries the information of the early stage of evolution. Furthermore, we analyze correlations of energy density fluctuations and find their behaviors are closely related with the properties of the medium such as relaxation time and sound velocity.

[1] J. D. Bjorken, Phys. Rev. D 27, 140 (1983).
[2] J. I. Kapusta, B. Muller, M. Stephanov, Phys. Rev. C 85, 054906 (2012).

Category

Theory

Collaboration (if applicable)

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Session Classification: Flash Talks

Track Classification: Collective Dynamics