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Fluctuation-dissipation relation and fluctuation theorem for causal hydrodynamic fluctuations

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Recently physics of thermal fluctuations of hydrodynamic fields, namely the hydrodynamic fluctuations, in high-energy nuclear collisions are actively discussed. In this talk I will discuss new modification terms [1] in fluctuation-dissipation relation (FDR), which determines the power of hydrodynamic noise fields, and also discuss its importance in the point of view the fluctuation theorem [2], which is a relation of the entropy production probability known in non-equilibrium statistical mechanics.

The effects of hydrodynamic fluctuations on heavy-ion observables such as flow coefficients and longitudinal decorrelation $r_n(\eta_a, \eta_b)$ are recently analyzed in event-by-event simulations by dynamical models [3-6]. Also the thermal fluctuations near the critical point also play an important role in the critical dynamics. In this sense the hydrodynamic fluctuations in dynamical models are becoming more and more important. The FDR used in dynamical models is normally obtained in the global equilibrium. However, in expanding systems such as matter created in the nuclear collisions, the FDR is non-trivial. I obtain new modification terms to the FDR in the second-order causal dissipative hydrodynamics by considering the linear-response in non-static and inhomogeneous backgrounds. I discuss its relation to the steady-state fluctuation theorem. Also, by performing the numerical simulations of non-linear relativistic fluctuating hydrodynamics assuming the Bjorken flow, I investigate the non-linear fluctuation effects to the fluctuation theorem.

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