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## Causal hydrodynamic fluctuation and its implementation in full (3+1)-D dissipative hydrodynamic simulation

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We formulate relativistic fluctuating hydrodynamics with causal hydrodynamic fluctuations and implement them into our dynamical model for more quantitative analysis of the transport coefficients of the matter created in heavy ion collisions.

The hydrodynamic fluctuations are thermal fluctuations arising in the event-by-event hydrodynamic evolution of the system, and its power spectrum is determined through the fluctuation-dissipation relation. While, the higher harmonics  $v_n$  ( $n > 2$ ) are systematically observed in RHIC and LHC and attract a lot of theoretical and experimental interests. Initial state fluctuations turned out to be important to explain these higher harmonics through event-by-event hydrodynamic simulations. The event-by-event hydrodynamic fluctuation, although its average is locally zero, also has effects on the higher harmonics and other observables in the same manner as the initial fluctuations which vanish in the averaged picture of the initial condition.

Recently, it is actively discussed to extract the shear viscosity from the experimental observables using hydrodynamic simulations with the initial fluctuations. The initial fluctuations are converted to observables through the response of the matter, which enables us to obtain information on the properties of the matter as well as on the initial state. But, the higher harmonics are created not only by initial state fluctuations, and the other sources of fluctuations such as the hydrodynamic fluctuation also play important roles. Therefore, to extract the quantitative properties of the quark-gluon plasma from experimental data, it is important to properly implement all the sources of fluctuations including hydrodynamic fluctuations in an integrated dynamical model with models of initial states, hydrodynamics of quark-gluon plasma and subsequent hadronic cascades.

First, we formulate relativistic fluctuating hydrodynamics with the hydrodynamic fluctuation [1] in the context of the causal dissipative hydrodynamics which are commonly used in dynamical models for heavy-ion collisions. In causal dissipative hydrodynamics, the hydrodynamic fluctuation of the dissipative currents becomes colored noise due to the fluctuation-dissipation relation. But, interestingly, noise turns out to be always white in the differential form of the constitutive equations, which comes from general properties of the response function of the dissipative currents including causality and resulting constraints on the structure of the constitutive equations. Next, we implement the hydrodynamic fluctuations into our integrated dynamical model and investigate the behavior of the hydrodynamic fluctuations in heavy-ion collisions and discuss effects on experimental observables. The effect can be more significant in higher orders of the harmonics  $v_n$ , and in smaller systems such as peripheral collisions or central pA collisions.

### References

[1] Koichi Murase, Tetsufumi Hirano, arXiv:1304.3243 [nucl-th]

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### On behalf of collaboration:

None

**Author:** MURASE, Koichi (The University of Tokyo)

**Co-author:** HIRANO, Tetsufumi (Sophia Univ)

**Presenter:** MURASE, Koichi (The University of Tokyo)

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