QUARK MATTER 2015
Sep. 27 – Oct. 3, 2015 Kobe, Japan

Contribution ID: **185** Type: **Poster**

Derivation of Causal Hydrodynamic Equation by Renormalization Group Method

Tuesday 29 September 2015 16:30 (2 hours)

We derive the second-order hydrodynamic equation systematically from the relativistic Boltzmann equation for multi-component and multi-conserved-charge systems by the renormalization-group method [1,2]. It is confirmed that the resultant microscopic expressions of the transport coefficients coincide with those derived in the Chapman-Enskog expansion method. Furthermore, we show that the microscopic expressions of the relaxation times have natural and physically plausible forms. We prove that the propagating velocities of the fluctuations of the hydrodynamical variables do not exceed the light velocity, and that the equilibrium state is stable for any perturbation described by our equation. We also confirm that the entropy production rate is positive definite quantity and our equation satisfies the Onsager's reciprocal theorem. All these confirmation strongly support the validity of our formulation.
[1] K. Tsumura, Y. Kikuchi, and T. Kunihiro, (2015), arXiv:1506.00846 [hep-ph].
[2] Y. Kikuchi, K. Tsumura, and T. Kunihiro, in preparation.

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Session Classification: Poster Session

Track Classification: Collective Dynamics