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

Contribution ID: **607** Type: **Poster**

Chiral magnetohydrodynamics from quantum field theory

Tuesday, 29 September 2015 16:30 (2 hours)

Hydrodynamics is a low-energy effective theory which describes a long-distance and long-time behavior of many-body systems. It has been recently pointed out that quantum anomalies affect macroscopic transport properties and generate novel anomaly-induced transports. One example is the chiral magnetic effect, which represents the existence of a dissipationless vector current along the magnetic field and is expected to occur in heavy-ion collisions.

For the description of the anomaly-induced transport in the QGP, we have established formalism, so-called anomalous hydrodynamics, that captures effects of quantum anomalies. Since the QGP consists of electrically charged particles, it is necessary to consider a back reaction to electromagnetic fields in order to describe the space-time evolution of them together with that of the QGP. However, in the conventional anomalous hydrodynamics, electromagnetic fields are treated as external ones and the back reaction is neglected. Moreover, the magnitude of magnetic fields is assumed to be small. Therefore, we need to construct chiral magnetohydrodynamics in the strong magnetic field in order to assess the contribution from anomalous transports.

In this study, considering the recent development of non-equilibrium statistical mechanics, we derive the chiral magnetohydrodynamics under strong magnetic fields from the underlying microscopic theory, that is, the quantum field theory. In order to derive the chiral magnetohydrodynamic equation, we use a solid basis in our previous study on the derivation of the first-order hydrodynamics [1], in which we assume that the local Gibbs distribution is realized at initial time. As a result, we derive the chiral magnetohydrodynamic equation with the the field theoretical expression of Green-Kubo formulas for the all transport coefficients.

References:

[1] T. Hayata, Y. Hidaka, M. Hongo, T. Noumi, [arXiv: 1504.04535]

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Session Classification: Poster Session

Track Classification: New Theoretical Developments