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Collectivity in intermediate-scale QGP and extended hydrodynamic regime

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The quark-gluon plasma (QGP) is a fluid at a long wavelength and becomes a collection of weakly-coupled partons at an asymptotically short wavelength. However, its properties at the "mesoscopic" length scale, which is too short for a fluid description and too long for a perturbative treatment, remain elusive. In this work, we consider the response of QCD-like plasma to energy/momentum disturbance as a function of the gradient. For both N=4 super-Yang Mills theory in strong coupling limit and kinetic theory under relaxation time approximation, we find that hydrodynamic modes continue dominating medium's response even in the region where Knudsen number is large. However, in this extended hydrodynamic regime, both the first-order and second-order hydrodynamics fail to characterize medium's behavior. Inspired by the recent development in extended hydrodynamics, such as Hydro+ [1], we construct a simple yet not trivial extension of the Muller-Israel-Stewart theory, namely MIS*, and show this novel framework can quantitatively describe hydrodynamic modes in both hydrodynamic and extended hydrodynamic regimes with a suitable choice of model parameters for representative microscopic theories with and without quasi-particle descriptions [2]. As an illustration, we apply MIS* to study how a Bjorken-expanding QGP responds to a moving energetic parton [3].

Refs.

[1] M. Stephanov and Yi Yin , "Hydro+: hydrodynamics with parametric slowing down and fluctuations near the critical point", Phys. Rev. D 98 (2018) 036006.

[2] Weiyao Ke and Yi Yin, in preparation.

[3] Weiyao Ke and Yi Yin, "Beyond the wake: non-hydrodynamic response of an expanding Quark-gluon plasma", PoS HardProbes2020 (2021) 187

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