Does QGP feature an extended hydro. regime?

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Abstract

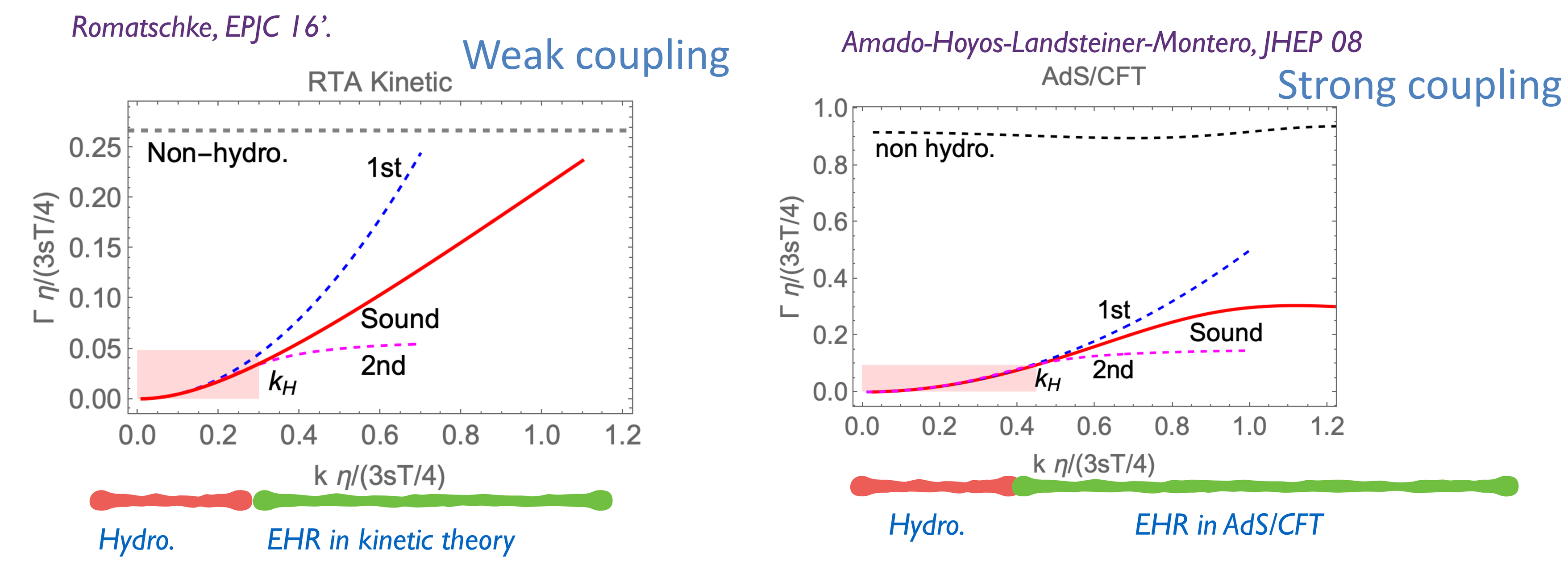
We investigate the response of the near-equilibrium QGP to perturbation at non-hydrodynamic gradients. We propose a conceivable scenario under which sound mode continues to dominate the medium response in this regime. We show this extended hydrodynamic regime (EHR) indeed exists for both the weakly-coupled kinetic equation in the relaxation time approximation (RTA) and the strongly-coupled N = 4 supersymmetric Yang-Mills (SYM) theory. We construct a simple but nontrivial extension of MIS theory, namely MIS*, and demonstrate that it describes EHR response for both RTA and SYM theory. This indicates that MIS* equations can potentially be employed to search for QGP EHR via heavy-ion collisions.

Extended hydro. dynamics regime (EHR)

Excitations (such as collective modes) determine the (linear) response of a medium to an in-homogeneous disturbance.

At small gradient (Hydro. regime), hydro. modes are gapped (smaller damping rate) from other excitations and dominate the response.

What would happen at non-hydrodynamic gradient in QCD-like systems?



Sound mode remains to be gapped at non-hydro. gradient in both RTA kinetic theory and N=4 SYM but its dispersion is different from hydro. calculation==> the existence of extended hydro. regime

EHR conjecture for QGP

We propose the existence of EHR as a conceivable scenario for QGP that sound continues dominating the response at non-hydro. gradient.

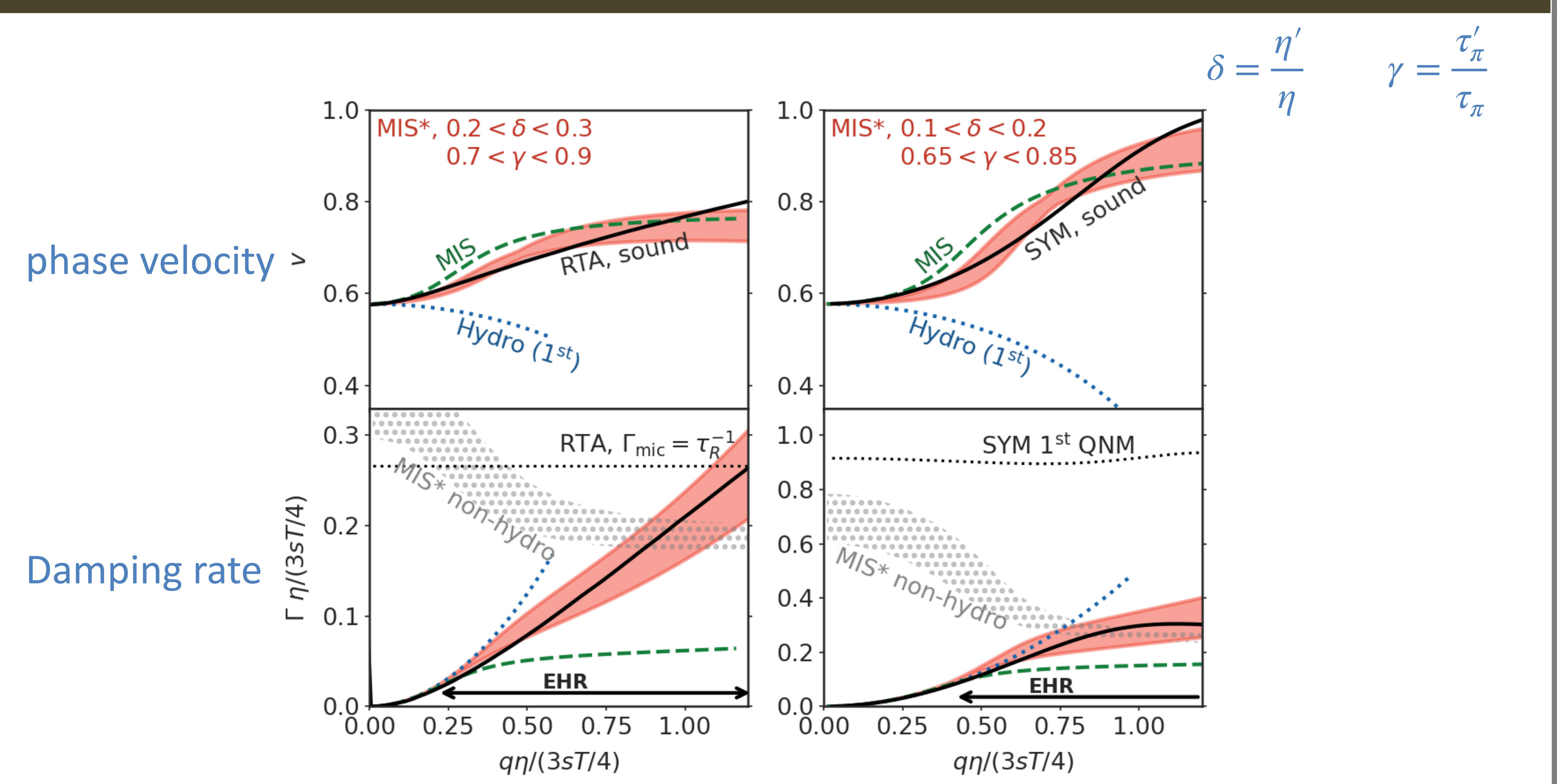
If true, one can use the properties of high-frequency sound to characterize the medium in non-hydro. regime.

To describe EHR, we construct an extension of MIS theory, namely MIS*.

$$T^{\mu\nu} = T^{\mu\nu}_{\rm ideal} + \pi^{\mu\nu}$$

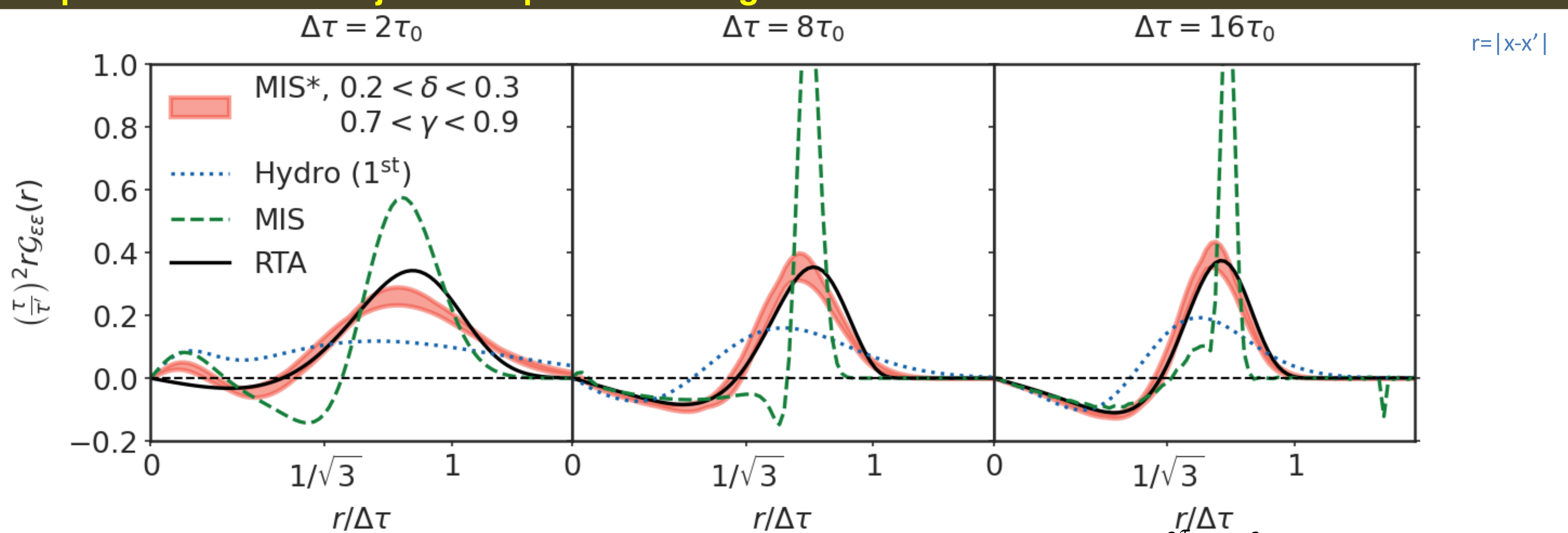
$$\pi^{\mu\nu} = -\eta' \partial^{<\mu} u^{\nu>} + \tilde{\pi}^{\mu\nu}$$

$$D\tilde{\pi}^{\mu\nu} = -\frac{1}{\tau'_\pi}\left(\tilde{\pi}^{\mu\nu} + (\eta - \eta')\partial^{<\mu}u^{\nu>}\right) - \ldots$$



MIS* is capable of describing sound dispersion in EHR.

Response function in Bjorken expansion background



Consider e.g. energy-energy response function from kinetic theory: $\delta\epsilon(\tau, x) = \int_{\tau_I}^{\tau} d\tau' \int_{x'} G_{\epsilon\epsilon}(\tau, \tau'; x - x')\, S_\epsilon(\tau', x') + \ldots$.

MIS* gives a reasonable description of the response function even if characteristic gradient is large (small Δτ=τ-τ').

Summary and outlook

We introduce extended hydro. regime (EHR) scenario for QGP-like system at intermediate scale that sound modes dominate the response.

Future: testing this scenario via observables associated with jet-medium interaction and small systems.