Long-range correlations in the deconfined phase of QCD

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Motivation

Problem

Perturbative resummation scheme ($g\ll 1$) describe QCD at the electric scale gT. However, important contribution from IR physics are missing. They are essential to understand dynamics , such as transport coefficients, in realistic conditions since at phenomenologically relevant temperatures, $T\sim 1\text{-}4T_C$, the QCD coupling is sizable $g\sim O(1)$. These shortcomings can in part be traced back to the origin of the magnetic scale g^2T, which cannot be trated perturbatively [1].

Approach

Gribov-Zwanziger framework [2] at finite temperature: fixing residual gauge transformations that remain after Fadeev-Popov. Generation of a new scale related to onset of confinement in the vacuum: the Gribov parameter γ_G: ~const. in the vacuum and g^2T at high-T [3]. The theory is renormalizable (Landau gauge) and suited for perturbative calculations. In the GZ theory,

$$D_{\mu\nu}(P) = \left(g_{\mu\nu} - \frac{P_\mu P_\nu}{P^2}\right)\frac{P^2}{P^4+\gamma_G^4}\,.$$

is the IR improved gluon propagator (Euclidean). Due to the modified pole structure, it embodies positivity violation, an important ingredient of a "confinement" scenario: reduction of physical states in the IR.

An important measure of collective behavior in a hot QGP is the self-energy of quarks and gluons: access to screening masses, dispersion relations and spectral functions. We calculate the quark self energy in the HTL limit with the internal gluon (loop) propagator given by the GZ form [4].

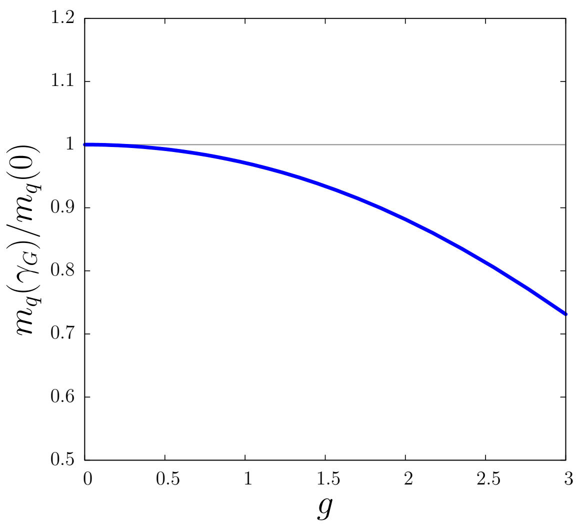

Fig. 1: The quark screening mass, normalized by the perturbative HTL value.

Screening mass

- We find a suppressed quark screening mass wrt. the HTL expectation: negative contribution from the presence of the IR scale, see Fig. 1. This can be understood as the suppression of the quark screening due to the presence of IR screened gluons.

Modified analytical structure

- The analytical structure of the quark propagator is modified due to complex conjugate structures from GZ propagator: allows pole contributions for the quark propagator close to the origin (IR).
- reproduce the conventional quasi-particle poles in the time-like regime (ω>p), see blue curves in Fig. 2: particle and hole (plasmino) excitations. Scaling for g≲2.
- Strikingly, we find a massless mode for ω < min(p,γ), protected by the novel magnetic scaling, w/ dispersion relation for this mode scales like $\omega = v_s p$, where $v_s^2 \approx 1/3$: reminiscent of hydrodynamical behavior.
- However, the residue is negative, $Z < 0$, implying negativity violation of the quark spectral function in the IR. Thus it cannot be a quasi-particle degree of freedom. Seen for the **first time** in the context of resummed perturbation theory. Usually, within HTL the space-like regime is the domain of Landau damping.

Conclusions & outlook

- Modified IR dynamics of the gluon sector can shed light on novel features of the quark-gluon plasma. These are related to manifestations of the long-range confinement effects surviving at finite temperatures in the plasma.
- The Gribov parameter at high-T scales as the (chromo)magnetic scale g^2T
- New, improved quark screening mass (including contributions from the magnetic scale).
- Novel magnetic scaling that allows for the existence of a massless mode in the IR. This comes with a negative spectral weight, indicating that this excitation is not a quasiparticle.
- Genuine non-Abelian effecs (QCD ≠ QED)
- In line with expectations from lattice and functional methods, see eg. [5]
- Interesting to study further the impact of IR improved gluons on transport coefficients, thermalization; relation to Cherenkov radiation and plasma instabilities.

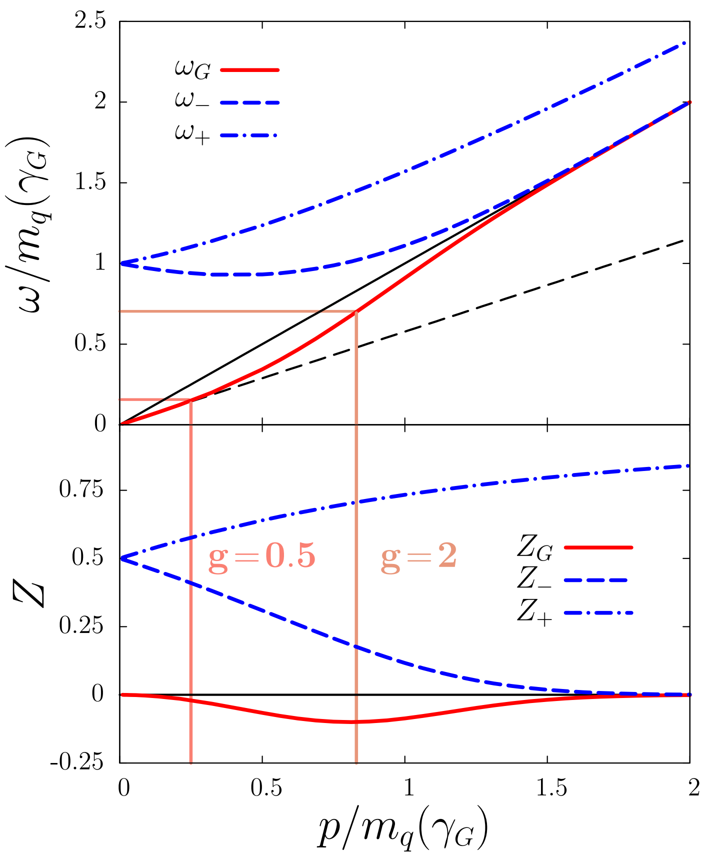

Fig. 2: Dispersion relations (upper panel) and the corresponding residues (lower panel) for three excitations found at high temperature.

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