Exploring jet transport coefficients in the strongly interacting quark-gluon plasma

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Dynamical QuasiParticle Model (DQPM)

- DQPM – effective model for the description of non-perturbative (strongly interacting) QCD based on lQCD EoS

- The QGP phase is described in terms of interacting quasiparticles - massive quarks and gluons - with Lorentzian spectral functions:

\[ \rho_j(\omega, p) = \frac{4\omega \gamma_j}{\left(\omega^2 - p^2 - M_j^2\right)^2 + 4\gamma_j^2 \omega^2} \]

- Field quanta are described in terms of dressed propagators with complex self-energies:
  
  - gluon propagator: \( \Delta^{-1} = P^2 - \Pi \)
  - gluon self-energy: \( \Pi = M_g^2 - 2i\gamma_g\omega \)
  - quark propagator: \( S^{-1} = P^2 - \Sigma_q \)
  - quark self-energy: \( \Sigma_q = M_q^2 - 2i\gamma_q\omega \)

- Real part of the self-energy - thermal masses
- Imaginary part of the self-energy - interaction widths of partons

P. Moreau et al., PRC 100, 014911 (2019)
**Partonic interactions in DQPM**

DQPM partonic cross sections: leading order diagrams

- Quark propagator:
  \[ q_i \rightarrow q_j \]
  \[ g + M_q \]
  \[ q^2 - M_q^2 + 2i\gamma_q q_0 \]

- Gluon propagator:
  \[ g_{\mu\nu} - g^{\mu\nu}q^2/M_g^2 \]
  \[ q^2 - M_g^2 + 2i\gamma_g q_0 \]

**Off-shell:**
Integration over final masses

**On-shell:**
Final masses = pole masses

- Off-shell:
  \[ S = 4 \text{ GeV}^2 \]
  - On-shell
  - Off-shell
  - pQCD limit
  - "True" pQCD

\[ \rightarrow \text{can reproduce pQCD cross sections} \]

\[ \rightarrow \text{strong } T \text{ dependence} \]
\[ \rightarrow \text{weak } \mu_B \text{ dependence} \]
Transport coefficients in kinetic theory

**On-shell:**
- integration over momentums
- masses = pole masses

\[ E^2 = m^2 + p^2 \]

\[
\langle \mathcal{O} \rangle^{\text{on}} = \frac{1}{2E_i} \sum_{j=q,q,g} d_j f_j \int \frac{d^3p_j}{(2\pi)^32E_j} \times \int \frac{d^3p_1}{(2\pi)^32E_1} \int \frac{d^3p_2}{(2\pi)^32E_2} \times (1 \pm f_1)(1 \pm f_2)\mathcal{O}|\mathcal{M}|^2(2\pi)^4\delta^{(4)}(p_i + p_j - p_1 - p_2)
\]

**Off-shell:**
- integration over momentums
- + two additional integrations over medium partons energy

\[
\frac{1}{2E} \rightarrow \int \frac{d\omega}{(2\pi)} \rho(\omega, p) \theta(\omega)
\]

\[
\langle \mathcal{O} \rangle^{\text{off}} = \frac{1}{2E_i} \sum_{j=q,q,g} d_j f_j \int \frac{d^4p_j}{(2\pi)^4} \rho(\omega_j, p_j) \theta(\omega_j) \times \int \frac{d^3p_1}{(2\pi)^32E_1} \int \frac{d^4p_2}{(2\pi)^4} \rho(\omega_2, p_2) \theta(\omega_2) \times (1 \pm f_1)(1 \pm f_2)\mathcal{O}|\mathcal{M}|^2(2\pi)^4\delta^{(4)}(p_i + p_j - p_1 - p_2)
\]

\[
\langle \mathcal{O} \rangle = \begin{cases} 
A, & \mathcal{O} = (p - p') \\
\frac{dE}{d\tau}, & \mathcal{O} = (E - E') \\
\hat{q}, & \mathcal{O} = (p_i^2 - p_i'^2)
\end{cases}
\]
Results: $\hat{q}$-hat

The DQPM $\hat{q}$-hat($T$) for elastic scattering of a jet quark vs other models

JET: K. M. Burke et al., PRC 90, 014909 (2014); IQCD: A. Kumar et al., arxiv:2010.14463;
LBT: Y. He et al., PRC 91 (2015); JETSCAPE: S. Cao et al. PRC 104, 024905 (2021); CSPM: A. Mishra et al., Physics 4, 315 (2022)
Results: q-hat and energy loss

Momentum dependence of the scaled q-hat

Momentum dependence of the energy loss

Summary:

➔ Transport coefficients q-hat and dE/dx are evaluated for the propagation of the jet parton (quark and gluon) through the strongly interacting QGP based on the DQPM

◆ q-hat coefficient is calculated as a function of medium temperature, jet momentum, jet mass, and chemical potential

◆ dE/dx is calculated as a function of jet momentum

➔ DQPM predicts stronger energy loss than pQCD models due to the elastic interaction of jet parton with non-perturbative QGP

➔ DQPM reproduces the pQCD limits for zero masses and widths of medium partons

Future:

➔ Investigate radiative processes