Jet momentum broadening in real-time lattice simulations of the glasma

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Initial Stages 2021

January 13, 2021

Based on

Code: gitlab.com/openpixi/curraun
Jets in the glasma

- **Jets**: highly energetic, focused particle “sprays” that originate from hard scatterings of partons **during the collision**
- Jets interact with all stages of the medium, including the pre-equilibrium glasma phase

Fig. from D. d’Enterria, *Jet quenching*, Landolt-Bornstein (2010) [arXiv:0902.2011]
Jets in the glasma

Fig. from A. Ipp, D. I. Müller, D. Schuh, PRD (2020) [arXiv:2001.10001]
Momentum broadening

- Model early-time jet as single parton (quark or gluon)
- No backreaction, color field of glasma as background
- Very high initial momentum, no deflection
- McLerran-Venugopalan model

Wong equations

\[
\frac{dp_{\mu}}{dt} = g Q^a(t) \frac{dx^\nu}{dt} F^a_{\mu\nu}(x(t))
\]

\[
\frac{dQ^a}{dt} = g \frac{dx^\mu}{dt} f^{abc} A^b_\mu(x(t)) Q^c(t)
\]
Momentum broadening

- Integrate Wong's equations
- Average over color charges of the jet and background field

Main result for a quark moving along $x$-axis ($i = y, z$):

$$\langle p_i^2(\tau) \rangle_q = \frac{g^2}{N_c} \int_0^\tau d\tau' \int_0^\tau d\tau'' \langle \text{Tr} \left[ f^i(\tau') f^i(\tau'') \right] \rangle$$

$$f^y(\tau) = U(\tau) (E_y(\tau) - B_z(\tau)) U^\dagger(\tau)$$

$$f^z(\tau) = U(\tau) (E_z(\tau) + B_y(\tau)) U^\dagger(\tau)$$

Color rotation matrix in temporal gauge $A^\tau = 0$:

$$U(\tau) = \mathcal{P} \exp \left( -ig \int_0^\tau d\tau' A_x(\tau') \right)$$
Results

- Accumulated momenta at transition time $\tau_0 = 0.6 \text{ fm}/c$
  \[ \langle p^2_{\perp} \rangle \approx Q_s^2 \]

- Infrared dependence $m$

- Gluonic jets
  \[ \frac{\langle p^2_{\perp} \rangle_g}{\langle p^2_{\perp} \rangle_q} = \frac{C_A}{C_F} = \frac{2N_c^2}{N_c^2 - 1} \]

- Broadening is anisotropic
  \[ \frac{\langle p^2_z \rangle}{\langle p^2_y \rangle} \approx 2 \]

Fig. from A. Ipp, D. I. Müller, D. Schuh, PLB (2020) [arXiv:2009.14206]
Anisotropy

Weak field approximation:
Initial field correlations related to momentum broadening
(see talk by D. Schuh)

▶ Difference in electric and magnetic correlators
▶ Anti-correlated regions surrounding magnetic flux tubes
▶ Result: momentum broadening anisotropy

Initial correlation functions for $E_z$ and $B_z$

Fig. from A. Ipp, D. I. Müller, D. Schuh, PRD (2020) [arXiv:2001.10001]
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Jet broadening parameter $\hat{q}$

Jet broadening parameter $\hat{q}$: accumulated (squared) momentum per unit time

$$\hat{q}_\perp(\tau) = \frac{d \langle p^2_\perp \rangle}{d\tau}$$

Most momentum is accumulated in the earliest stages of the glasma!

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