Jet Quenching in Strongly Magnetized QGP: pQCD vs. AdS/CFT

based on
1605.00188 Shiyong Li, KM, Ho-Ung Yee

Kiminad Mamo

University of Illinois at Chicago

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Outline

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1. Motivation
2. $\hat{q}$ in pQCD
3. $\hat{q}$ in pQCD with strong magnetic field $eB \gg T^2$

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- therefore, it would be interesting to explore how this huge magnetic field affects jet quenching

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- the total scattering rate of the jet from thermal LLL quarks $\Gamma^{\mathrm{single}} = \int d^3\mathbf{q}\frac{d\Gamma^{\mathrm{single}}_{LLL}}{d^3\mathbf{q}}$ can be found from the imaginary cut of the jet self-energy, i.e.,

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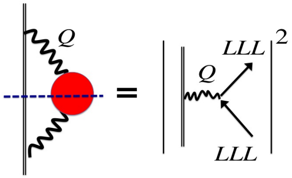

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\begin{aligned}
\Gamma^{\rm single} \quad &\sim \quad \alpha_s \int d^4Q \left(n_B(q^0) + n_F(p^0+q^0)\right) \rho^{\rm g}_{\alpha\beta}(Q) \\
&\times \quad {\rm Tr}\left[\gamma^\beta\gamma^0\mathcal{P}(\mathbf{p}+\mathbf{q})\gamma^\alpha\gamma^0\mathcal{P}(\mathbf{p})\right] \delta(p^0+q^0-\sqrt{(\mathbf{p}+\mathbf{q})^2+M^2})
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- the gluon spectral density $\rho^{\rm g}_{\alpha\beta}(Q)$ is [Fukushima et al. 2015]

$$\rho^{\rm g}_{\alpha\beta}(Q) \sim \frac{Q_{\parallel\alpha}Q_{\parallel\beta} \times \alpha_s \times e^{-\frac{\mathbf{q}_\perp^2}{2eB}} \times \mathrm{sgn}(q^0)\delta(Q_\parallel^2)}{\left(\frac{\mathbf{q}_\perp^2}{eB} + \mathrm{const.} \times \alpha_{\rm s} \times \mathrm{e}^{-\frac{\mathbf{q}_\perp^2}{2\rm eB}}\right)^2}$$

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$$\frac{d\Gamma^{\text{single}}}{d^2\mathbf{q}_\perp} \sim \frac{\alpha_s^2(1+v)(eB)\,Te^{-\frac{\mathbf{q}_\perp^2}{2eB}}}{\left(\mathbf{q}_\perp^2 + \mathrm{const.} \times \alpha_\mathrm{s} \times \mathrm{eB} \times \mathrm{e}^{-\frac{\mathbf{q}_\perp^2}{2\mathrm{eB}}}\right)^2}$$

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- and the jet quenching parameter to complete leading order in α_s is

$$\hat{q} \equiv \frac{1}{v}\int d^2\mathbf{q}_\perp \frac{d\Gamma^{\text{single}}}{d^2\mathbf{q}_\perp}\mathbf{q}_\perp^2 \sim (1+1/v)\,\alpha_s^2(eB)\,T\Big(\log\left(1/\alpha_s\right) + \text{const.}\Big)$$

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$$\frac{d\Gamma^{\mathrm{single}}}{dq_y\, dq_z} \approx \frac{\frac{1}{v}\alpha_s^2 n_B(q_z)\, q_z\, (eB)\, e^{-\frac{\left(q_z^2/v^2+q_y^2\right)}{2eB}}}{\left(\frac{q_z^2}{v^2} + q_y^2 + \mathrm{const.} \times \alpha_\mathrm{s} \times \mathrm{eB} \times \mathrm{e}^{-\frac{\left(q_z^2/v^2+q_y^2\right)}{2eB}}\right)^2}$$

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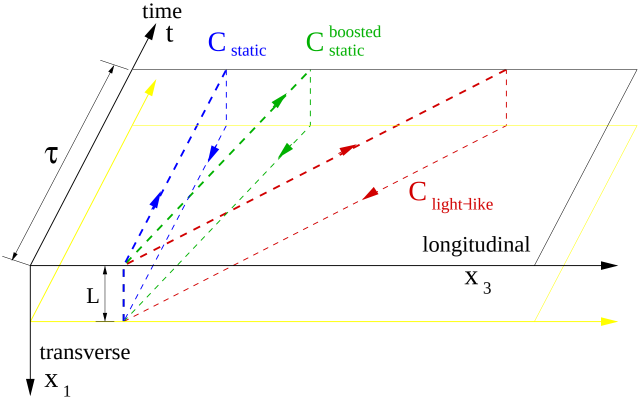
time
t
τ
C static
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C light-like
longitudinal
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L
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- in the presence of a strong magnetic field $\mathcal{B} \gg T^2$ in the bulk [D'Hoker et al. 2009]

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- the Hawking temperature T of the black hole

$$T = \frac{1}{4\pi}\sqrt{g_{zz}(r_h)f'(r_h)g^{rr\prime}(r_h)} = \frac{r_h}{2\pi\mathcal{R}^2}$$

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$$\hat{q}(v) = -4\frac{T_s^{\parallel}}{v}\lim_{\omega\to 0}\frac{\text{Im}\,G_R^{\parallel}(\omega)}{\omega} = \frac{2T_s^{\parallel}}{\pi\alpha' v}g_{xx}(r_s) = \frac{2}{3\pi}\sqrt{1+\frac{1}{v^2}}\sqrt{\lambda}\mathcal{B}T$$

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$$\hat{q} = \frac{1}{\pi\alpha'}\left(\int_0^{u_h} du \frac{1}{G_{xx}}\sqrt{\frac{G_{uu}}{G_{tt}+G_{zz}}}\right)^{-1} = \frac{4}{3}\frac{\sqrt{\lambda}\mathcal{B}T}{\log(\mathcal{B}/T^2)}$$

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Summary

- when the jet is parallel to the strong magnetic field $\mathcal{B} \gg T^2$

$$\hat{q}_{pQCD} \sim (1 + 1/v)\, \lambda^2 \mathcal{B} T \Big(\log(1/\alpha_s) + \text{const.} \Big) + \mathcal{O}\big(\mathrm{T}^2/\mathcal{B}\big)$$

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- when the jet is perpendicular to the strong magnetic field $B \gg T^2$

$$\hat{q}_{pQCD(z)} \sim v^2 \lambda^2 \mathcal{B}^{3/2} + \mathcal{O}\left(T^2/\mathcal{B}\right)$$

$$\hat{q}_{pQCD(y)} \sim \lambda^2 \mathcal{B}^{3/2} + \mathcal{O}\left(T^2/\mathcal{B}\right)$$

  and

$$\hat{q}_{AdS/CFT(z)} \sim v^2 \sqrt{\lambda} \mathcal{B}^{3/2} + \mathcal{O}\left(T^2/\mathcal{B}\right)$$

$$\hat{q}_{AdS/CFT(y)} \sim \sqrt{\lambda} \mathcal{B}^{3/2} + \mathcal{O}\left(T^2/\mathcal{B}\right)$$

Thank You!