Inclusive Gluon Production in DIS

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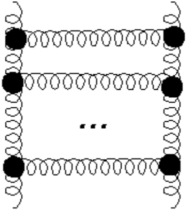
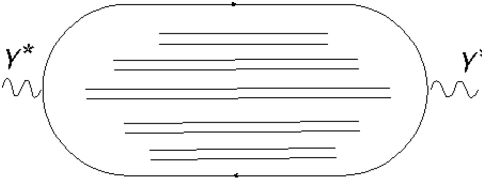


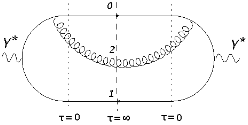


Gluon Ladder vs Dipole Cascade (Mueller '94)

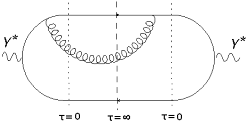
$$\frac{\partial N(x_1,x_0)}{\partial y} = \frac{\bar{\alpha_s}}{2\pi}\int d^2x_2 \frac{x_{10}^2}{x_{12}^2 x_{20}^2}\left\{N(x_1,x_2)+N(x_2,x_0)-N(x_1,x_0)-N(x_1,x_2)N(x_2,x_0)\right\}$$

BFKL (BK) equations

- Large N_c limit (no non-planar diagrams)
- Instantaneous interactions
- No late emissions (Mueller, Chen '95)



A



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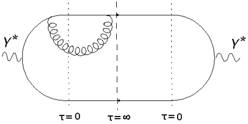
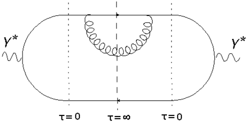
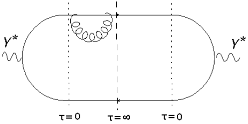


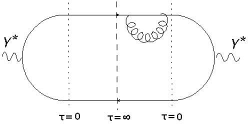
C



D

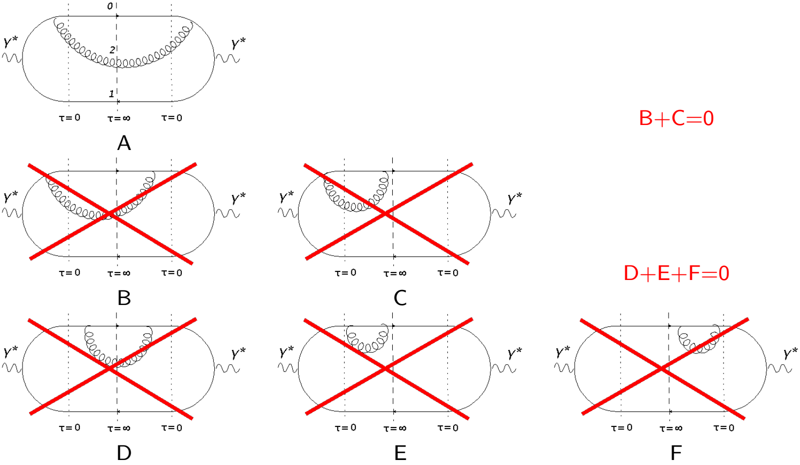


E



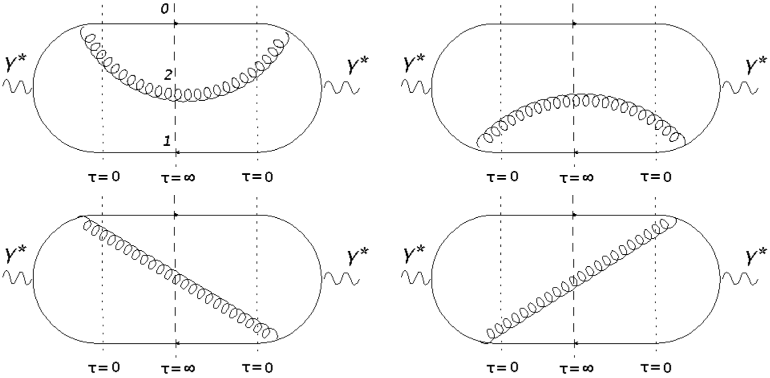
F

- Large N_c limit (no non-planar diagrams)
- Instantaneous interactions
- No late emissions - real-virtual cancellations (Mueller, Chen '95)



B+C=0

D+E+F=0

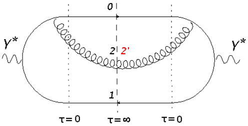


$$\left(\frac{x_{12}}{x_{12}^2} - \frac{x_{02}}{x_{02}^2}\right)\left(\frac{x_{12}}{x_{12}^2} - \frac{x_{02}}{x_{02}^2}\right) \Rightarrow \frac{x_{10}^2}{x_{12}^2 x_{20}^2}$$

BFKL Kernel

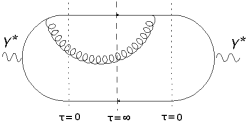
Inclusive gluon production

- ~~No late emissions- real-virtual cancellation~~ Do not cancel



A

$k_\perp$ fixed $\rightarrow x_2$ in A and $x_{2'}$ in A^*



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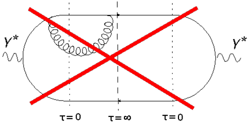

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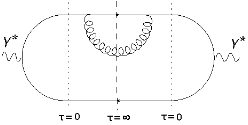

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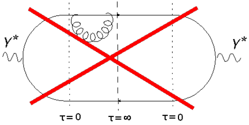

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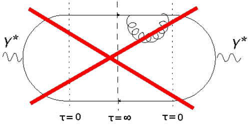
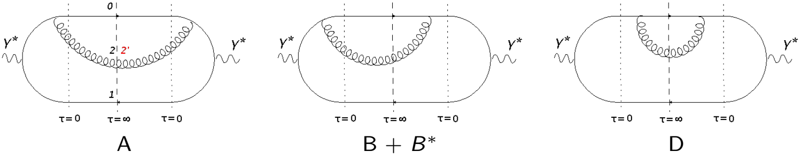


F

Inclusive gluon production (no evolution) Kovchegov '01



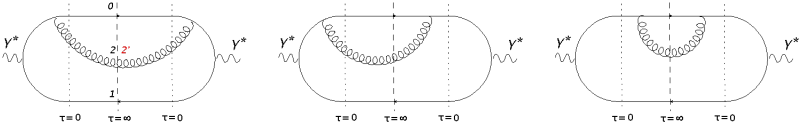
- Interaction with quark line x_1 cancels
- Effectively, dipole x_{20} ($x_{2'0}$) interacts twice (author missed 2)

$$\frac{d\sigma^{q\bar{q}A}(x_1, x_0)}{d^2k\ dy} = \frac{\bar{\alpha_s}}{2\pi}\frac{1}{(2\pi)^2}\int d^2b d^2x_2 d^2x_{2'} e^{-ik(x_2-x_{2'})}\times$$

$$\left\{\frac{x_{02}}{x_{02}^2}\frac{x_{02'}}{x_{02'}^2}\left(1 - e^{-2x_{02}^2Q_s^2/4} - e^{-2x_{02'}^2Q_s^2/4} + e^{-2x_{22'}^2Q_s^2/4}\right)\right.$$

$$\left.-\frac{x_{02}}{x_{02}^2}\frac{x_{12'}}{x_{12'}^2}\left(e^{-2x_{10}^2Q_s^2/4} - e^{-2x_{02}^2Q_s^2/4} - e^{-2x_{12'}^2Q_s^2/4} + e^{-2x_{22'}^2Q_s^2/4}\right) + (0\leftrightarrow 1)\right\}$$

Inclusive production with evolution (Kovchegov, Tuchin '02)



$$\frac{d\sigma^{q\bar{q}A}(x_1, x_0)}{d^2k\; dy} = \frac{\bar{\alpha}_s}{2\pi}\frac{1}{(2\pi)^2}\int d^2b d^2x_2 d^2x_{2'} e^{-ik(x_2 - x_{2'})} \times$$

$$\left\{ \frac{x_{02}}{x_{02}^2}\frac{x_{02'}}{x_{02'}^2}\left(1 - e^{-2x_{02}^2 Q_s^2/4} - e^{-2x_{02'}^2 Q_s^2/4} + e^{-2x_{22'}^2 Q_s^2/4}\right)\right.$$

$$\left. -\frac{x_{02}}{x_{02}^2}\frac{x_{12'}}{x_{12'}^2}\left(e^{-2x_{10}^2 Q_s^2/4} - e^{-2x_{02}^2 Q_s^2/4} - e^{-2x_{12'}^2 Q_s^2/4} + e^{-2x_{22'}^2 Q_s^2/4}\right) + (0 \leftrightarrow 1)\right\}$$

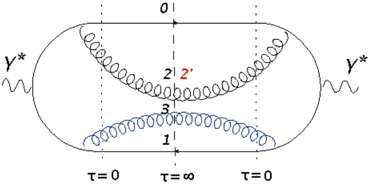
- No evolution: interaction only with gluon and q ($\bar{q}$) from which it was emitted
- Authors claimed: the same for evolution

Inclusive production with evolution (Kovchegov, Tuchin '02)

Claim: replace $1 - e^{-2x^2 Q_s^2/4}$ by scattering amplitude of adjoint (gluonic) dipole

$$N_G(x,b,y) = 2N(x,b,y) - N^2(x,b,y)$$

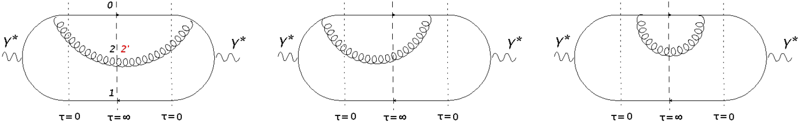
since interaction happens only with gluon and q ($\bar{q}$) from which it was emitted (all other contributions cancel). Let's check !



Emit a softer gluon "3". This has no diagram to cancel with.

E.Levin, A.P. (in preparation)

Go back and check the "no evolution" case



A B + B^* D

Contribution to total cross section

$$A \Rightarrow \quad 1 + e^{-2x^2_{22'}Q_s^2/4} - e^{-(x^2_{12}+x^2_{02})Q_s^2/4} - e^{-(x^2_{12'}+x^2_{02'})Q_s^2/4}$$

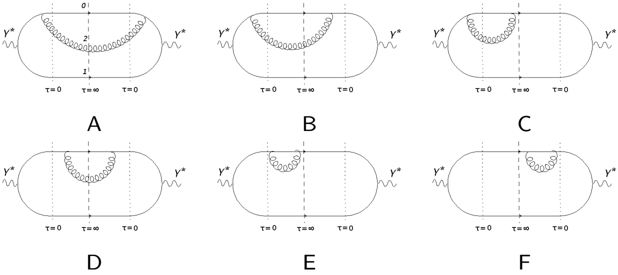
$$B \Rightarrow \quad 1 + e^{-2x^2_{02}Q_s^2/4} - e^{-(x^2_{12}+x^2_{02})Q_s^2/4} - e^{-x^2_{10}Q_s^2/4}$$

$$D \Rightarrow \quad 2(1 - e^{-x^2_{10}Q_s^2/4})$$

$$A + B + B^* + D \Rightarrow \quad 1 + e^{-2x^2_{22'}Q_s^2/4} - e^{-2x^2_{02}Q_s^2/4} - e^{-2x^2_{02'}Q_s^2/4}$$ OK!

The problem is that not all EXP in all lines can be associated with the same function N_G. In fact, we have *three different types* of functions with distinct evolutions !!!

Evolution for cross section of dipole with different coordinates in $A(A^*)$.



$$\frac{\partial M^A(12;12')}{\partial y} =$$

$$\frac{\bar{\alpha}_s}{2\pi}\int d^2x_3\left(\frac{x_{23}}{x_{23}^2}-\frac{x_{13}}{x_{13}^2}\right)\left(\frac{x_{2'3}}{x_{2'3}^2}-\frac{x_{13}}{x_{13}^2}\right)\left(M^A(13;13)+M^A(32;32')-M^A(12;12')-\frac{1}{2}M^A(13;13)M^A(32;32')\right)$$

$$-\frac{\bar{\alpha}_s}{2\pi}\int d^2x_3\left(\frac{x_{23}}{x_{23}^2}-\frac{x_{13}}{x_{13}^2}\right)\left(\frac{x_{2'3}}{x_{2'3}^2}-\frac{x_{23}}{x_{23}^2}\right)M^{BC}(13;12')\{1-N(32)\}+\textbf{terms from } B^*, C^*$$

$$-\frac{1}{2}\frac{\bar{\alpha}_s}{2\pi}\int d^2x_3\left(\frac{x_{23}}{x_{23}^2}-\frac{x_{2'3}}{x_{2'3}^2}\right)^2 M^{DEF}(12;12')$$

$$\frac{\partial M^{BC}(12;10)}{\partial y} = -\frac{\bar{\alpha_s}}{2\pi}\int d^2x_3 \left(\frac{x_{23}}{x_{23}^2} - \frac{x_{13}}{x_{13}^2}\right)\left(\frac{x_{2'3}}{x_{2'3}^2} - \frac{x_{23}}{x_{23}^2}\right) M^{BC}(13;10)\{1 - N(32)\}$$

$$-\frac{1}{2}\frac{\bar{\alpha_s}}{2\pi}\int d^2x_3 \left(\frac{x_{23}}{x_{23}^2} - \frac{x_{2'3}}{x_{2'3}^2}\right)^2 M^{DEF}(12;10)$$

$$\frac{\partial M^{DEF}(10;10)}{\partial y} = -\frac{1}{2}\frac{\bar{\alpha_s}}{2\pi}\int d^2x_3 \left(\frac{x_{23}}{x_{23}^2} - \frac{x_{2'3}}{x_{2'3}^2}\right)^2 M^{DEF}(10;10)$$

- for $x_2 = x_2'$ contributions from BC and DEF vanish and we obtain BK equation
- at high energy those also vanish due to negative intercept and $1 - N$ factor

Conclusions

- No simple "gluonic" dipole structure $N_G(x) = 2N(x) - N^2(x)$
- Corrected inclusive cross section in high energy limit

$$\frac{d\sigma^{q\bar{q}A}(x_1, x_0)}{d^2k\ dy} = \frac{\bar{\alpha}_s}{2\pi}\frac{1}{(2\pi)^2}\int d^2b d^2x_2 d^2x_{2'} e^{-ik(x_2 - x_{2'})}\left(\frac{x_{02}}{x_{02}^2} - \frac{x_{12}}{x_{12}^2}\right)\left(\frac{x_{02'}}{x_{02'}^2} - \frac{x_{12'}}{x_{12'}^2}\right)\times$$

$$\left\{M^A(02, 02') + M^A(12, 12') - \frac{1}{2}M^A(02, 02')M^A(12, 12')\right\}$$

with $M^A(12, 12')$ solution to "generalized" BK equation

$$\frac{\partial M^A(12; 12')}{\partial y} =$$

$$\frac{\bar{\alpha}_s}{2\pi}\int d^2x_3\left(\frac{x_{23}}{x_{23}^2} - \frac{x_{13}}{x_{13}^2}\right)\left(\frac{x_{2'3}}{x_{2'3}^2} - \frac{x_{13}}{x_{13}^2}\right)\left(M^A(13; 13) + M^A(32; 32') - M^A(12; 12') - \frac{1}{2}M^A(13; 13)M^A(32; 32')\right)$$

- This result one can directly obtain ignoring effect of "real-virtual" cancellations (non-cancellations)