Gluon Correlations in small-x Evolution

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arXiv:0805.0710 [hep-ph]

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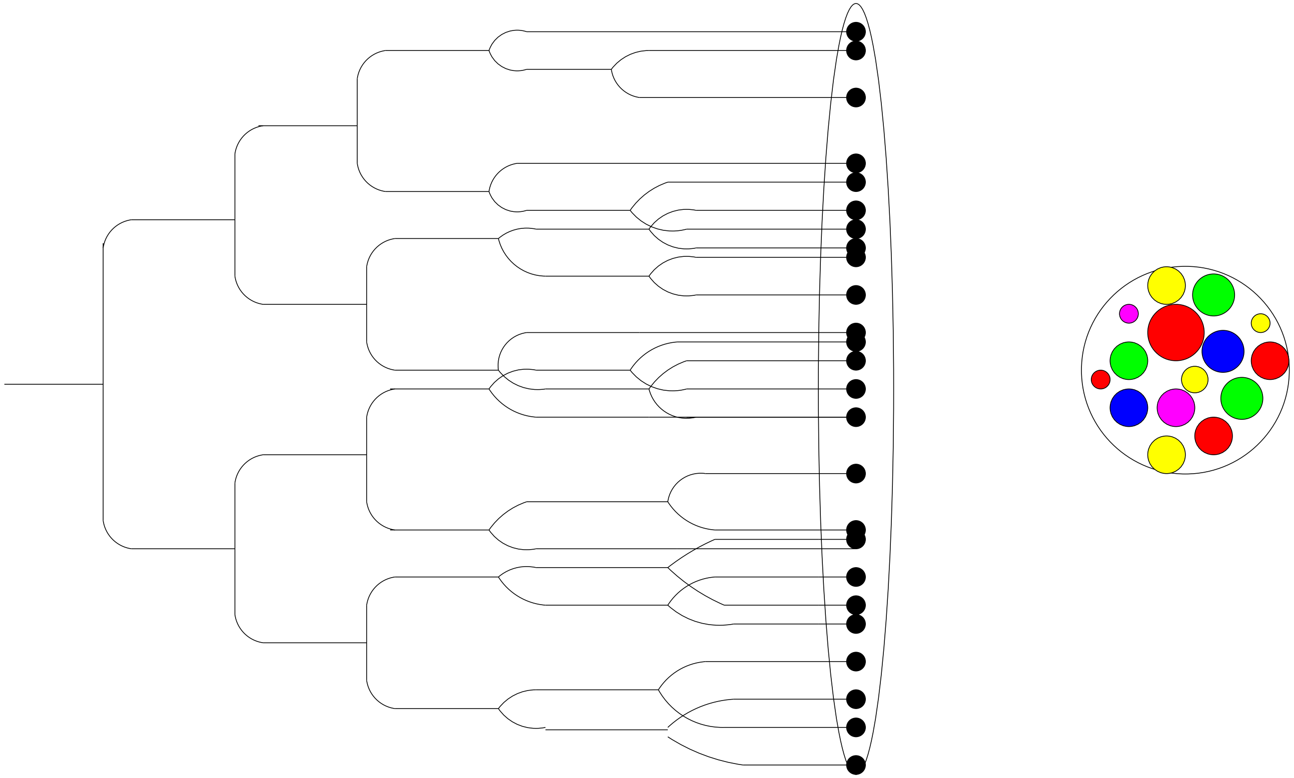
Outline

- Evolution equations and correlations
- Calculating the correlations:
  - Analytical approach
  - Numerical approach
- Summary and Outlook

Evolution towards smaller x

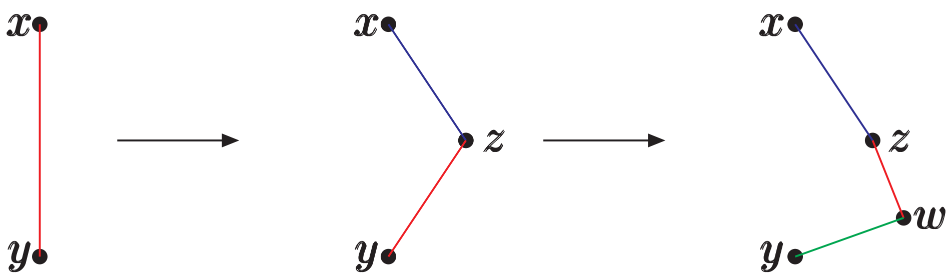


- Hadron contracted to a “pancake” consisiting of gluons at different transverse positions.

High Energy Evolution Equations

- Start with dipole (x, y). The evolution of T with $Y \equiv \ln 1/x$ is given by

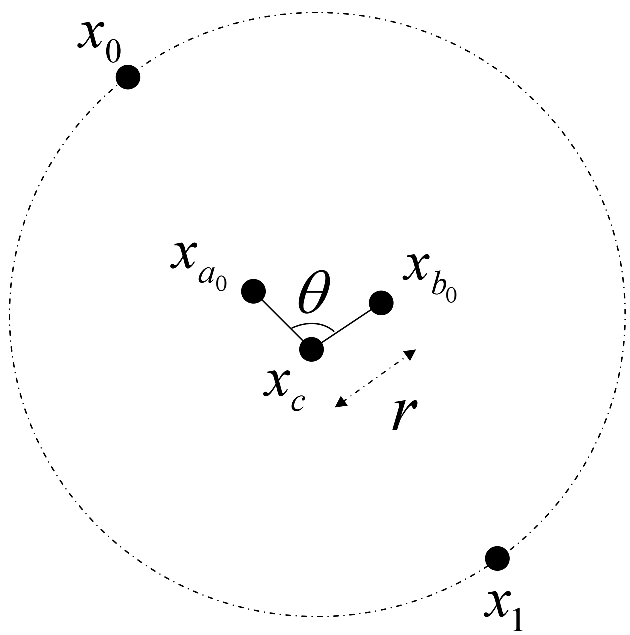
$$\partial_Y T_{xy} = \int d^2z \frac{d\mathcal{P}}{dY\, d^2z}\{-T_{xy} + T_{xz} + T_{zy} - T^{(2)}_{xz;zy}\}$$



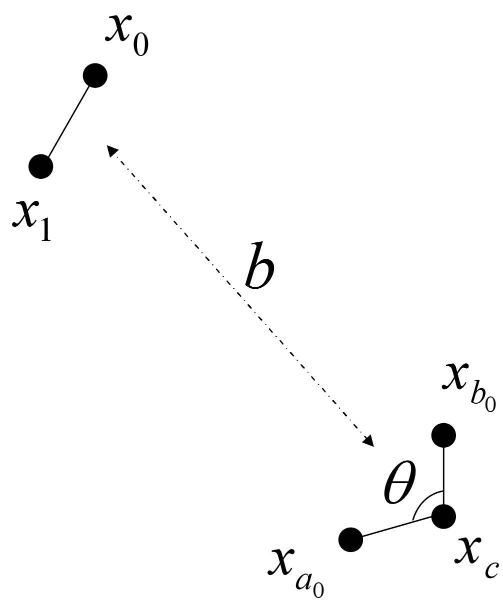
- No correlations: $T^{(2)} = T \cdot T \Rightarrow$ Hierarchy closes down to single equation; BK-eq.
- Important to know value of $R \equiv T^{(2)}/T^2$.

Dipole Densities

- To estimate R analytically one needs to evaluate the double dipole density $n^{(2)}$.
- $n^{(2)}$ has previously been calculated for spatially disconnected dipoles. Power-like correlations were found, implying $n^{(2)} \gg n^2$. This in turn implies $T^{(2)} \gg T^2$, *i.e.* $R \gg 1$.
- To make quantitative predicitions for R however, numerical approach needed.
- In numerical approach, Hadron wavefunction explicitely constructed: One has knowledge of all $n^{(k)}$ on an event-by-event basis.



(a)



(b)

Analytic Results

- For $x_{01} >> b, r$ ($\gamma \approx 0.82$ always):

$$R \sim \left(\frac{x_{01}}{r}\right)^{2(2\tilde{\gamma}-\gamma)} e^{2(\chi(1/2)-\chi(\tilde{\gamma}))Y}, \quad \chi'(\tilde{\gamma})Y = \ln \frac{x_{01}^2}{r^2}$$

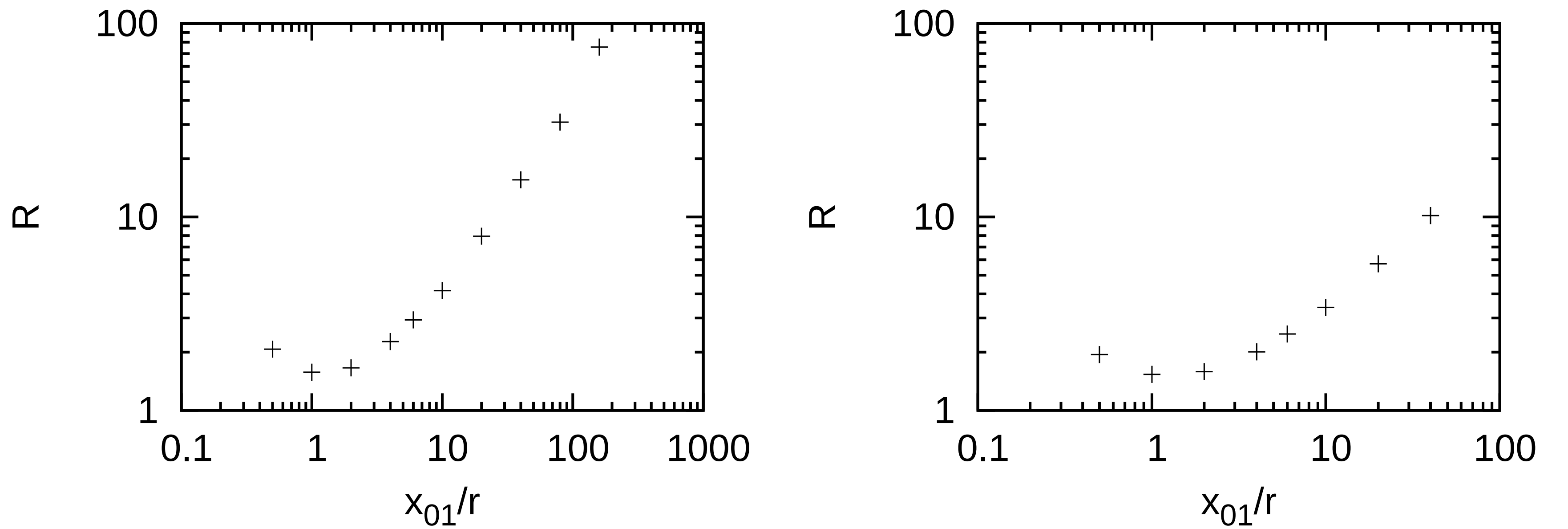
- For $r \sim b >> x_{01}$:

$$R \sim \left(\frac{r}{x_{01}}\right)^{2(2\tilde{\gamma}-\gamma)} e^{2(\chi(1/2)-\chi(\tilde{\gamma}))Y}, \quad \chi'(\tilde{\gamma})Y = \ln \frac{r^2}{x_{01}^2}$$

- For $b >> x_{01}, r$:

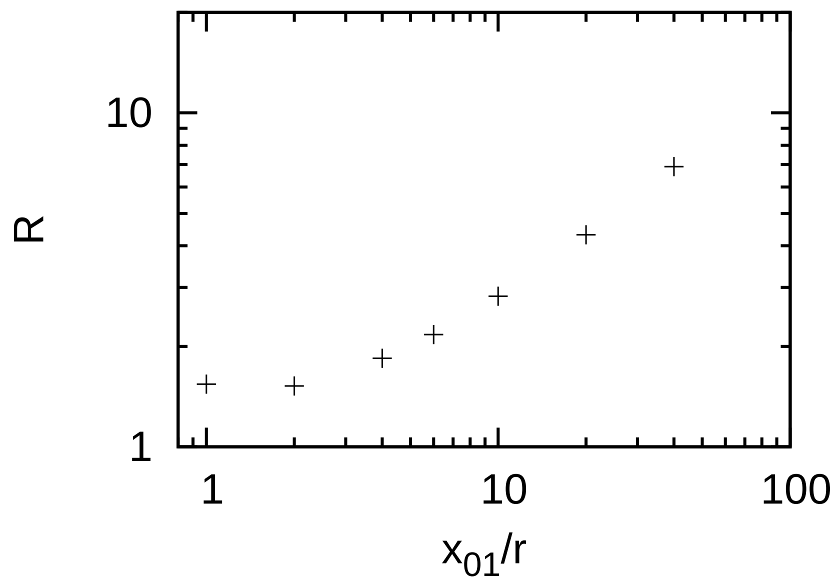
$$R \sim \left(\frac{b^2}{x_{01}r}\right)^{2(2\tilde{\gamma}-\gamma)} e^{2(\chi(1/2)-\chi(\tilde{\gamma}))Y}, \quad \chi'(\tilde{\gamma})Y = \ln \frac{b^4}{x_{01}^2 r^2}$$

Results for $b = 0, Y = 6, 8$



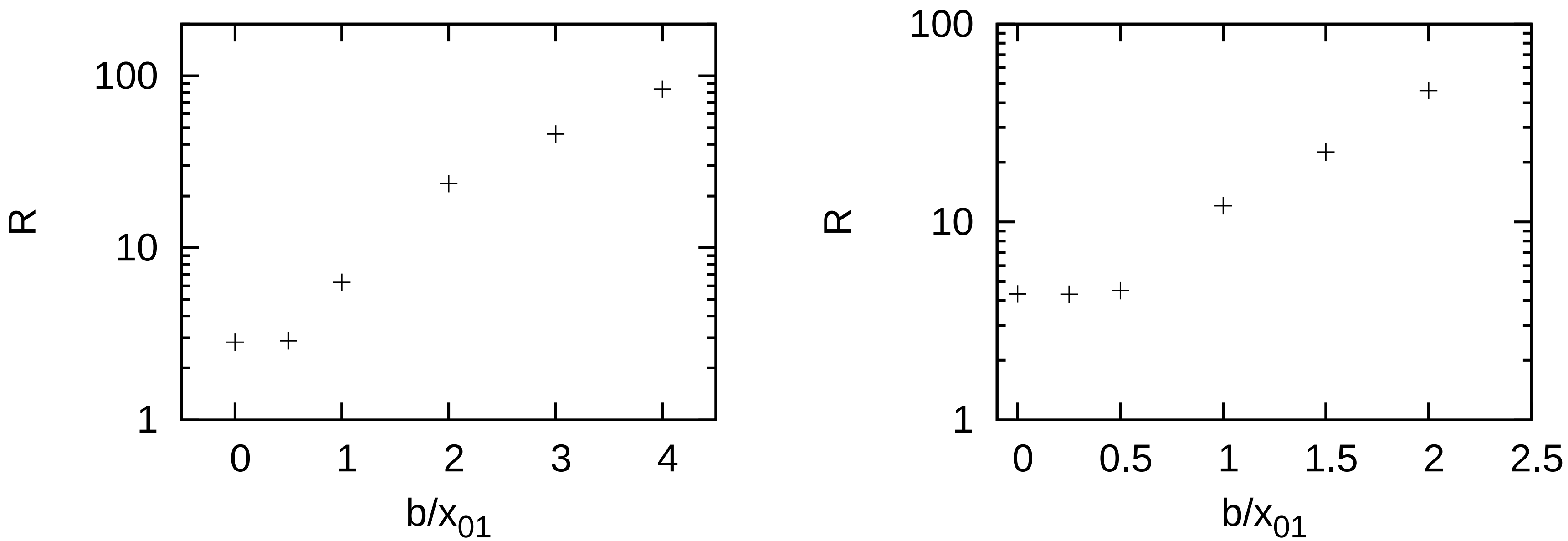
- Power-like behaviour consistent with analytic estimates. At $Y = 8$ and $x_{01}/r = 5$ and 20, analytic result: $\omega = 0.52$ and 0.76 while numerical result gives 0.60 and 0.80.

Results for $b = 0$, $Y = 10$



- Y dependence consistent with analytic estimates. For asymmetric configurations R decreases faster. We note that $R \gtrsim 1.5$ always.
- Beyond $Y = 10$, $T^{(2)} > 1$ so we cannot go any further.

b Dependence

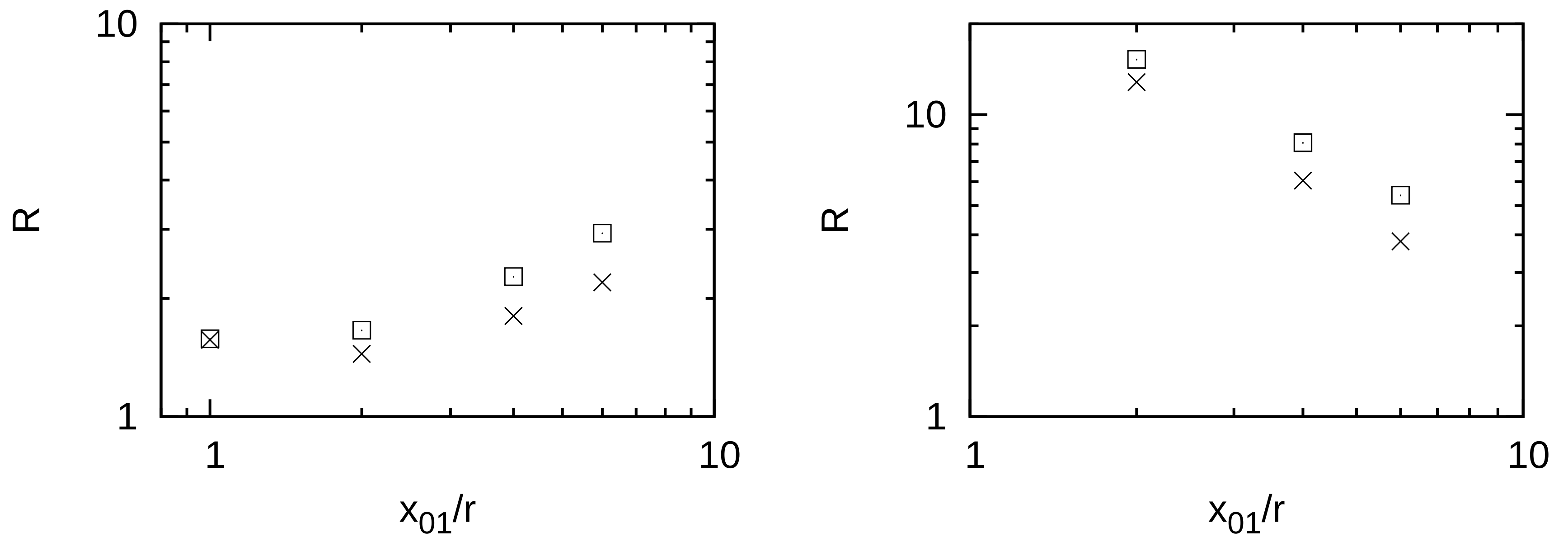


- Results for $x_{01} = 10\,r$ and $x_{01} = 20\,r$ at $Y = 10$. R constant as long as $b < x_{01}$, but it increases fast as $b \gtrsim x_{01}$.

Running Coupling

- In nature the coupling is running so important to include running α_s.
- The avaliable NLL studies suggest that $\bar{\alpha}_s$(min(r, r_1, r_2)) should be used in the splitting $r \longrightarrow r_1, r_2$.
- The inclusion of the running α_s is straightforward. In practice, however, simulations are very time consuming and we have not been able to perform as detalied analysis.
- Analytic calculations not easy, postponed for a future study.

Results for Running α_s



- Results for $b = 0$ and $b = 5\,r$ at $Y = 6$. At $Y = 8$, $R : 1.6 \rightarrow 1.5$ at $x_{01} = 2\,r$ and $b = 0$, and $R : 11.6 \rightarrow 9.4$ at $b = 5\,r$.

Summary and Outlook

- We find power-like correlations which lead to a strong violation of the factorization assumption $T^{(2)} = T \cdot T$.
- Analytic estimates confirmed by numerical analysis, and we have been able to quantitatively study the value of R.
- Physical consequences of the large correlations should be explored.
- More results for running α_s desirable.
- Studies of higher order correlations, calculation of $T^{(p)}$ for $p > 2$. Few analytical results. Numerics straightforward but can be time consuming.