

Non-minimal coupling contribution to DIS at low x in Holographic QCD

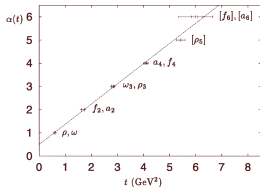
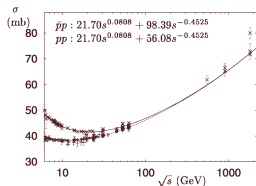
Robert Carcassés Quevedo
with M. Costa and A. Amorim



Talk plan

- Brief review of Pomeron phenomenology
- Brief review of previous work on the same line
- Motivation for the non-minimal coupling
- Holographic computation of structure function
- Results
- Future

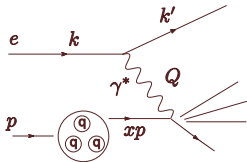
Pomeron: a historical introduction



Regge Theory:

$$\mathcal{A}^\pm(s, t) \sim \Gamma(-\alpha^\pm(t)) \left(\frac{s}{s_0}\right)^{\alpha^\pm(t)}$$

Deep Inelastic Scattering



DESY

hadronic tensor:

$$\langle H, P | [J^\mu(x), J^\nu(0)] | H, P \rangle$$

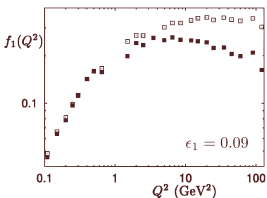
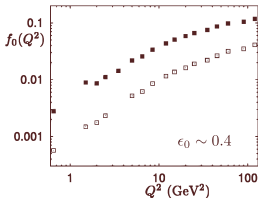
structure functions:

$$F_2(Q^2, x) \sim \text{Im} \int \text{tr} \left[\gamma^\mu \gamma^* \gamma^\nu \right]$$

well known dependence
on Q , small x is
challenging...

New DIS data: the Hard Pomeron

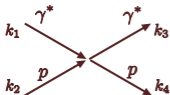
$$F_2(Q^2, x) = f(Q^2)x^{-\epsilon(Q^2)} = f_0(Q^2)x^{-\epsilon_0} + f_1(Q^2)x^{-\epsilon_1} + \dots$$



Donnachie and Landshoff
hep-ph/0105088
hep-ph/9806344

Goal

Use the gauge/string duality to compute



$$\int dx e^{ik \cdot x} \langle P | \mathcal{T} (J_\mu(x) J_\nu(0)) | P \rangle$$

in the Regge limit

$$k_1 = \left(\sqrt{s}, -\frac{Q^2}{\sqrt{s}}, 0 \right), \quad -k_3 = \left(\sqrt{s}, \frac{q_\perp^2 - Q^2}{\sqrt{s}}, q_\perp \right),$$
$$k_2 = \left(\frac{M^2}{\sqrt{s}}, \sqrt{s}, 0 \right), \quad -k_4 = \left(\frac{M^2 + q_\perp^2}{\sqrt{s}}, \sqrt{s}, -q_\perp \right).$$

Improved Holographic QCD model

$$S = M^3 N_c^2 \int d^5 x \sqrt{-g_s} e^{-2\Phi} (4g_s^{\mu\nu} \partial_\mu \partial_\nu + R_s + V(\Phi))$$
$$ds^2 = e^{2A(z)} (dz^2 + \eta_{\mu\nu} dx^\mu dx^\nu)$$

Dictionary:

$$\log E \leftrightarrow A(z)$$

$$T_{\mu\nu} \leftrightarrow h_{\mu\nu}$$

$$\text{tr} F^2 \leftrightarrow \phi$$

$$\text{tr} F \wedge F \leftrightarrow a$$

Successfully explains:

- Confinement
- Asymptotic freedom
- Glueball spectrum data
know from lattice
computations

Building Higher Spin EOM

The EOM of the higher spin fields should satisfy:

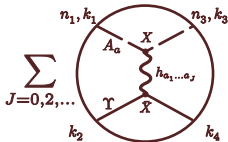
- Be compatible with graviton EOM for $J=2$
- The coupling with the dilaton to be the one of the closed string in the graviton's trajectory
- Reproduce known free CFT case for constant dilaton.

We propose:

$$\left(\nabla^2 - 2e^{-2A}\dot{\Phi}\nabla_z - \frac{\Delta(\Delta-4)}{L^2} + J\dot{A}^2e^{-2A} + (J-2)e^{-2A} \left(a\ddot{\Phi} + b(\ddot{A} - \dot{A}^2) + c\dot{\Phi}^2 \right) \right) h_{\alpha_1 \dots \alpha_J}^{TT} = 0$$

Witten diagram: minimal coupling

We consider the tree level exchange of those higher spin fields belonging to graviton Regge trajectory



Minimal coupling vertex in X :

$$\kappa_J \int d^5 X \sqrt{-g} e^{-\Phi} F_{b_1 a} D_{b_2} \dots D_{b_{J-1}} F_{b_J}^a h^{b_1 \dots b_J}$$

Non-minimal coupling motivation

For AdS or flat space, there are only two possible cubic couplings between these fields

$$F^{ac} F^b{}_c h_{ab}, \quad F^{ac} F^{bd} \nabla_c \nabla_d h_{ab}$$

in general this does not hold. For concreteness, we will consider the action

$$S_A = -\frac{1}{4} \int d^5 X \sqrt{-g} e^{-\Phi} (F_{ab} F^{ab} + \beta R_{abcd} F^{ab} F^{cd}),$$

and we will find the coupling with the graviton by linearizing.

Linearizing and generalizing

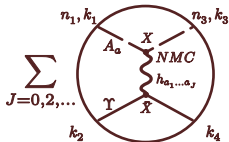
$$\delta S = -\frac{1}{2} \int d^5 X \sqrt{-\bar{g}} e^{-\Phi} \left(F^{ab} F^c{}_b h_{ac} \rightarrow \text{M.C.} \right. \\ \left. + \frac{\beta}{2} h_{ap} \bar{R}^p{}_{bcd} F^{ab} F^{cd} - \beta F^{ac} F^{bd} \bar{\nabla}_a \bar{\nabla}_b h_{cd} \right) \rightarrow \text{N.M.C.}$$

the non-minimal cubic interaction generalizes to

$$\beta_J \int d^5 X \sqrt{-\bar{g}} e^{-\Phi} \left(F^{ca_1} \bar{\nabla}^{a_2} \dots \bar{\nabla}^{a_{J-1}} F^{a_J d} \bar{\nabla}_c \bar{\nabla}_d \right. \\ \left. + \frac{1}{2} F^{a_1 b} \bar{\nabla}^{a_2} \dots \bar{\nabla}^{a_{J-1}} F^{cd} \bar{R}^a{}_{bcd} \right) h_{a_1 \dots a_J}$$

Witten diagram: non-minimal coupling

Non-minimal coupling contribution to F_2



After taking the Regge limit

$$F_2(x, Q^2) = \sum_n \left(f_n^{\text{MC}}(Q^2) + f_n^{\text{NMC}}(Q^2) \right) x^{1-j_n},$$

Further details

$$f_n^{\text{NMC}}(Q^2) = \tilde{g}_n Q^{2j_n} \int dz e^{-(j_n - \frac{3}{2})A} \left(f_Q^2 \tilde{\mathcal{D}}_{\perp} + \frac{f_Q^2}{Q^2} \tilde{\mathcal{D}}_{\parallel} \right) \psi_n,$$

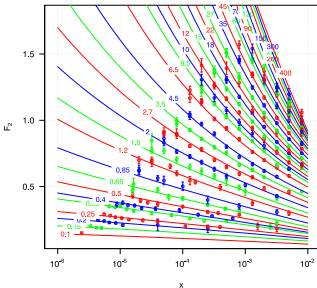
where $\tilde{g}_n \sim \beta_{j_n(0)}$ and

$$\tilde{\mathcal{D}}_{\perp} = e^{-2A} \left(\dot{A} \partial_z + \dot{A}^2 + \dot{A} \dot{B} \right),$$

$$\tilde{\mathcal{D}}_{\parallel} = e^{-2A} \left(\partial_z^2 - (\dot{A} - 2\dot{B}) \partial_z + \ddot{B} + \ddot{A} + \dot{B}^2 - \dot{A} \dot{B} \right)$$

with $B = \Phi - A/2$

Results



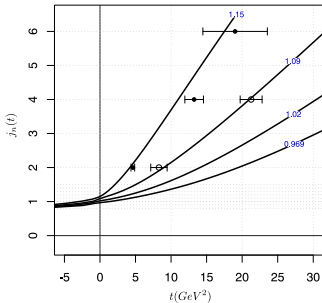
Best fit for F_2

Number of points: 249

$$\chi_{d.o.f}^2 = 1.1$$

$l_s^{-1} = 6.93$	$g_0 = -0.154$	$\tilde{g}_0 = 0.0707$
$a = -4.68$	$g_1 = -0.424$	$\tilde{g}_1 = -0.0378$
$b = 4.85$	$g_2 = 2.12$	$\tilde{g}_2 = -0.248$
$c = 0.665$	$g_3 = -0.721$	$\tilde{g}_3 = 0.363$
$d = -0.328$		
$\beta = -0.026$		

Regge trajectories



— current model

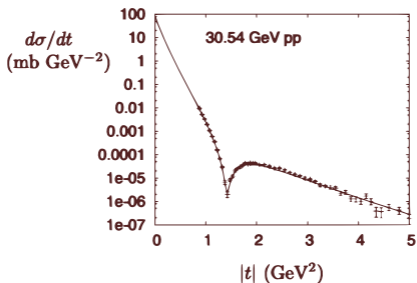
● glueball lattice masses
○ masses

Conclusions

We considered the contribution of a non-minimal coupling in a holographic Pomeron model:

- The contribution is encoded in the operators $\tilde{\mathcal{D}}_{\perp}$ and $\tilde{\mathcal{D}}_{\parallel}$.
- Fit of $F_2(x, Q^2)$ improves, $\chi^2_{d.o.f.}$ decrease to 1.1.
- The scale of the non-minimal coupling is in the range of the mass difference between the spin 2 and spin 4 glueballs.

Future: differential cross-sections...



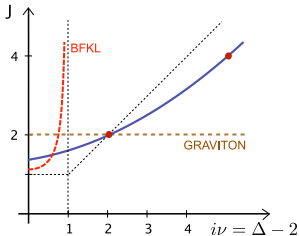
Future: HQCDP package

<https://github.com/rcarcasses/HQCD-P>

The screenshot shows the GitHub repository page for `rcarcasses/HQCD-P`. At the top, there is a search bar and navigation links for Pull requests, Issues, Marketplace, and Explore. The repository name is `rcarcasses/HQCD-P`, with 1 Unwatch, 0 Stars, and 0 Forks. Below the repository name are tabs for Code, Issues (5), Pull requests (0), Projects (0), Wiki, Insights, and Settings. The repository description is "An R package for the Pomeron in Holographic QCD". There are tags for `pomeron`, `high-energy-physics`, `r`, and `holography`. Statistics show 213 commits, 1 branch, 1 release, 2 contributors, and MIT license. The current branch is `master`. Action buttons include "Create new file", "Upload files", "Find file", and "Clone or download". A commit history table is visible below.

Commit	Message	Time
<code>cd0e3d5</code>	Preventing partial name matching between <code>lzN</code> and <code>lzNBar</code> attributes. I...	10 days ago
	Putting back documentation, some files renaming	5 months ago
	Added the file that contains <code>exp_data</code> of an scattering	5 months ago

Diffusion limit



For the term related to the anomalous dimension of the dual operator we propose:

$$\frac{\Delta(\Delta - 4)}{L^2} = \frac{2}{l_s^2} (J - 2) \left(1 + \frac{d}{\sqrt{\lambda}} \right) + \frac{1}{\lambda^{4/3}} (J^2 - 4)$$