THE TWO-COMPONENT NON-PERTURBATIVE POMERON AND THE G-UNIVERSALITY

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Abstract

In this communication we present a generalization of the Donnachie-Landshoff model inspired by the recent discovery of a 2-component Pomeron in LLA-QCD by Bartels, Lipatov and Vacca. In particular, we explore a new property, not present in the usual Regge theory - the G-Universality - which signifies the independence of one of the Pomeron components on the nature of the initial and final hadrons. The best description of the $pp, pp, \pi^\pm p, K^\pm p, \gamma\gamma$ and $\gamma p$ forward data is obtained when G-universality is imposed. Moreover, the $\ell n^2$'s behaviour of the hadron amplitude, first established by Heisenberg, is clearly favoured by the data.

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The Donnachie-Landshoff model \[1\] - denoted as \(X_s\) in the following - is very successful in describing \(\sigma_T\) and forward \((t = 0)\) \(\rho\) data for \(\bar{p}p, pp, \pi^\pm p, K^\pm p, \gamma\gamma\) and \(\gamma p\) scatterings: \(\chi^2/dof = 1.020\) for 16 parameters, 383 data points and \(\sqrt{s} \geq 9\) GeV \[2\].

In the present communication I will explore a QCD-inspired generalization of this model. The results are obtained in collaboration with P. Gauron \[3\].

Recently, Bartels, Lipatov and Vacca \[4\] discovered the existence of a 2-component Pomeron in LLA. The first component is associated with 2-gluon exchanges and corresponds to an intercept

\[
\alpha_{P}^{2g} \geq 1. \tag{1}
\]

The second component is associated with 3-gluon exchanges with \(C = +1\) and corresponds to an intercept

\[
\alpha_{P}^{3g} = 1. \tag{2}
\]

This last component is exchange-degenerate with the 3-gluon \(C = -1\) Odderon. It is therefore useful to explore possible 2-component Pomeron generalizations of the 1-component \(X_s\) Pomeron

\[
\sigma_{AB}(s) = Z_{AB} + X_{AB}(s) + Y_{AB}^+ s^{\alpha_+ - 1} \pm Y_{AB}^- s^{\alpha_- - 1}, \tag{3}
\]

where \(\sigma_{AB}(s)\) are total cross-sections,

\[
X_{AB}(s) = X_{AB}s^{\alpha_p - 1} \tag{4}
\]

\[
= X_{AB} \ln s \tag{5}
\]

\[
= X_{AB} \left[ \ln^2 \left( \frac{s}{s_0} \right) - \frac{\pi^2}{4} \right], \tag{6}
\]

and \(\alpha_p, \alpha_+\) and \(\alpha_-\) are Reggeon intercepts; \(Z_{AB}, X_{AB}, Y_{AB}^+, s_0\) are constants. The + sign in front of the \(Y_{AB}^-\) term in eq. (3) corresponds to \(\{A = \bar{p}, \pi^-, K^-, B = p\}\) and the - sign to \(\{A = p, \pi^+, K^+, B = p\}\). If \(A = \gamma\) in eqs. (3)-(6), then \(B = \gamma, p\) and \(Y_{AB}^- = 0\). An implicit scale factor of 1 \((\text{GeV})^2\) is present in the Reggeon and \(\ln s\) terms.

The first model in eqs. (3)-(6) - denoted as \(Z + X_s\) - in the following - corresponds to a generalized Donnachie-Landshoff approach \[2\] \[5\] \[6\]; the second - denoted as \(Z + X \ln s\) - to the well known dipole approach \[7\]; the third - denoted as \(Z + X \ln^2 s\) - to the Heisenberg-Froissart-Martin form first considered in 1952 by W. Heisenberg \[8\]. The \(\rho\)-parameter is calculated from (3) by using the known \(s \rightarrow se^{-\pi/2}\) crossing rule.

We study, in particular, the following properties:
1. The G-universality ("G" from "gluon") expressed by (see eqs. (3)-(6))

$$X_{AB}(s) = X(s),$$

i.e. independence of $X_{AB}$ on $A$ and $B$ ($A, B =$ hadrons only), a property not present in the usual Regge theory.

2. The weak exchange-degeneracy

$$\alpha_+ = \alpha_-, \quad Y_{AB}^+ \neq Y_{AB}^-.$$ (8)

The results for the simultaneous description of $\bar{p}p, pp, \pi^\pm p, K^\pm p, \gamma\gamma$ and $\gamma p$ reactions are given in Tables I (fits of $\sigma_T$ data only) and II (fits of $\sigma_T$ and $\rho$ data).

Table 1: Results of the fits of $\sigma_T$ data. The symbol = in the $\alpha_+$ column means weak exchange-degeneracy ($\alpha_+ = \alpha_-$).

| Model | $G$- exchange | Universality | degeneracy | $\alpha_+$ | $\alpha_-$ | $N_{par}$ | $\chi^2/\text{dof}$ |
|-------|----------------|--------------|-------------|------------|------------|-----------|----------------|
|       |                | Yes | No | Yes | No |         |               |
| $X s^t$ |                | x   | x  |     |   | 0.66±0.02 | 0.45±0.02 | 16 | 0.931 |
|        |                |     | x  |   |   | =         | 0.48      | 15 | 1.009 |
| $Z + X s^t$ |            | x   | x  |     |   | 0.618±0.021 | 0.465±0.021 | 17 | 0.936 |
|        |                |     | x  |   |   | =         | 0.491±0.023 | 16 | 0.980 |
|        |                | x   | x  |     |   | 0.526±0.029 | 0.479±0.023 | 17 | 0.835 |
|        |                |     | x  |   |   | =         | 0.487±0.023 | 16 | 0.836 |
| $Z + Xln s$ |             | x   | x  |     |   | 0.826±0.013 | 0.468±0.022 | 16 | 0.865 |
|        |                |     | x  |   |   | =         | 0.586±0.019 | 15 | 1.281 |
|        |                | x   | x  |     |   | 0.658±0.007 | 0.485±0.022 | 16 | 1.066 |
|        |                |     | x  |   |   | =         | 0.610±0.016 | 15 | 1.286 |
| $Z + Xln^2 s$ |            | x   | x  |     |   | 0.653±0.026 | 0.465±0.022 | 17 | 0.939 |
|        |                |     | x  |   |   | =         | 0.491±0.023 | 16 | 0.990 |
|        |                | x   | x  |     |   | 0.583±0.077 | 0.476±0.023 | 17 | 0.822 |
|        |                |     | x  |   |   | =         | 0.478±0.024 | 16 | 0.822 |
|        |                | x   | x  |     |   | =         | **0.48**   | **15** | **0.819** |

It can be seen from Tables I-II that the G-universality leads to a clear improvement of the description of all the considered data. Moreover, the
Table 2: Results of the fits of $\sigma_T$ and $\rho$ data. The symbol $\equiv$ has the same meaning as in Table 1.

| Model                  | Universality | degeneracy | $\alpha_+$ | $\alpha_-$ | $N_{par}$ | $\chi^2$/dof |
|-----------------------|--------------|------------|------------|------------|-----------|--------------|
| $X s^4$               | Yes          | No         | 0.66± 0.02 | 0.45± 0.02 | 16        | 1.020        |
|                       | Yes          | No         | =          | 0.48       | 15        | 1.320        |
| $Z + X s^4$           | x            | x          | 0.641±0.012| 0.440±0.015| 17        | 1.024        |
|                       | =            |            | =          | 0.494±0.013| 16        | 1.203        |
| $Z + X \ell n s$      | x            | x          | 0.602±0.014| 0.458±0.016| 17        | 0.986        |
|                       | =            |            | =          | 0.500±0.013| 16        | 1.092        |
| $Z + X \ell n^2 s$    | x            | x          | 0.816±0.001| 0.450±0.012| 16        | 0.941        |
|                       | =            |            | =          | 0.569±0.001| 15        | 1.769        |
|                       | x            | x          | 0.691±0.005| 0.465±0.015| 16        | 1.250        |
|                       | =            |            | =          | 0.592±0.008| 15        | 1.944        |
|                       | x            | x          | 0.651±0.017| 0.442±0.016| 17        | 1.015        |
|                       | =            |            | =          | 0.475±0.014| 16        | 1.142        |
|                       | x            | x          | 0.552± 0.048| 0.453± 0.017| 17        | 0.927        |
|                       | =            |            | =          | 0.457±0.015| 16        | 0.933        |

G-universality leads to a mild violation of the weak exchange-degeneracy ($\alpha_+-\alpha_-\simeq0.1$), in constant with the non-universality cases. These two independent features could hardly be considered as numerical accidents. It is therefore important to explore the validity of the 2-component G-universal Pomeron in all the other (non-forward) existing data.

A remarkable result is the fact that the forward data clearly favour the maximal Heisenberg-Froissart-Martin $\ell n^2 s$ behaviour of the hadron scattering amplitude $[8]$ : the absolute minimum of $\chi^2$/dof is precisely obtained for the G-universal $\ell n^2 s$ form of the amplitude. Our $\chi^2$/dof is better than that given in the last edition of "Review of Particle Physics" $[2]$.

Let us also note that the dipole model, corresponding to a $\ell n s$ behaviour of the scattering amplitude, has a serious pathology : the first component of the Pomeron $Z_{AB}$ has a negative contribution to the total cross-sections. Therefore this $\ell n s$ fit has to be dismissed. The
above pathological feature of the $\ell n s$ model was already remarked in J.R. Cudell et al. \cite{2}, but it was omitted from the "Review of Particle Physics" \cite{2}.

The theoretical and numerical details will be presented elsewhere \cite{3}.

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