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CURRENT ALGEBRA
AND THE NATURE OF THE POMERANCHUK MECHANISM

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A B S T R A C T

The fixed j -plane singularity at $j = 1$ in quark Green's functions implied by local current algebra is used as input in the Gribov Regge calculus to describe high energy hadron-hadron scattering. By including the two π intermediate state in the t channel, we obtain a moving pole with trajectory

$$\alpha_{\mathbf{P}}(t) \cong 1.06 + 0.26t$$

which appears to be a very good description of the Pomeranchuk mechanism up to the highest available energies.

In the framework of the massive quark model (MQM) ¹⁾ a deep connection is strongly suggested between current algebra and the scaling phenomena on one hand and the nature of hadronic diffractive scattering on the other. According to such a description, Bjorken scaling and the notion of local isospin current algebra leading to the celebrated Adler sum rule ²⁾ imply the existence in the angular momentum plane of the quark Green's functions of a fixed pole at $j = 1$, carrying the quantum numbers of the vacuum.

This input pole, which one may call "primeval Pomeron", will manifest itself in purely hadronic scattering when we try to develop a perturbative description of ¹⁾⁻³⁾ scattering amplitudes in terms of the fundamental building blocks represented by the quark Green's functions. In this approach the lowest order term with vacuum t channel quantum number is an approximately factorizable fixed pole at $j = 1$. Furthermore this pole is approximately imaginary and corresponds to the first diagram in Fig. 1.

Fig. 1

The remaining diagrams in Fig. 1 unitarize this fixed pole since the corresponding iteration satisfies unitarity in the t channel, in which the two pion contribution predominates. The resulting j plane singularity is a moving pole at $j = \alpha_P(t)$, with $\alpha_P(0) = 1 + \epsilon_0$, where ϵ_0 is a small positive constant.

In this letter we shall show, by employing the j plane calculus developed by Gribov ⁴⁾, that ϵ_0 is determined by the fixed pole residue. We use the Gribov approach instead of attempting a GPT-type analytic continuation of the t channel equations ⁵⁾, since the latter requires a detailed knowledge of the underlying analytic structure of the amplitudes involved, which has not yet been spelled out in detail in the MQM.

Let us recall and emphasize one very important and peculiar property of the MQM according to which the quark Green's functions are damped along the real axis faster than any power in the quark mass squared variables ¹⁾. This means that the MQM has the prerequisite of a Gribov calculus, albeit a rather degenerate one.

Our basic ingredient is the $q\bar{q}$ scattering amplitude $G_{\alpha_1 \dots \alpha_4}(K_1, K_2, K_3)$ (Fig. 2a), which we write in terms of its Mellin transform

$$G_{\alpha_1 \dots \alpha_4}(k_1, k_2, k_3) = \int \frac{dj}{2\pi i} (s_{12})^{j-1} g_{\alpha_1 \dots \alpha_4}(j, t_{13}, k_1^2, \dots) \quad (1)$$

where $s_{ij} = (K_i + K_j)^2$ and $t_{ij} = (K_i - K_j)^2$; $\{\alpha_i\}$ are the spinor indices of the quarks.

Fig. 2

Separating the leading singularity, i.e., the "primeval Pomeron", and assuming it is s channel helicity conserving, we write (1) as

$$G_{\alpha_1 \dots \alpha_4}(k_1, k_2, k_3) = \delta_{\alpha_1 \alpha_3} \delta_{\alpha_2 \alpha_4} \int \frac{dj}{2\pi i} s_{12}^j \frac{g(t_{13}, k_1^2, k_3^2) g(t_{24}, k_2^2, k_4^2)}{j-1} + G_{\alpha_1 \dots \alpha_4}^{NL} \quad (2)$$

We shall calculate the diagrams in Fig. 1 for the case of $\pi\pi$ scattering both for simplicity and because the two pion contribution in the t channel plays an important role in our approach.

The kinematics of the lowest order term (Fig. 1a) for $\pi^a \pi^b$ scattering is reported in Fig. 3. The corresponding amplitude is

$$F_0(s, t) = \int \frac{d^4 k}{(2\pi)^4} \int \frac{d^4 k'}{(2\pi)^4} \int \frac{d^4 q'}{(2\pi)^4} \psi_{\alpha_1 \alpha_1'}^a \psi_{\alpha_2 \alpha_2'}^b \psi_{\alpha_3 \alpha_3'}^{a*} \psi_{\alpha_4 \alpha_4'}^{b*} G_{\alpha_1 \dots \alpha_4}^{[1]} G_{\alpha_1' \dots \alpha_4'}^{[2]} \quad (3)$$

where $\psi_{\alpha_1 \alpha_2}^a(K_1^2, K_2^2)$ is the π^a - $q\bar{q}$ vertex function.

Fig. 3

We get in a straightforward fashion for the j plane projection of $F_0(s, t)$,

$$A_0(j, t) = \int ds s^{-j} F_0(s, t) \quad (4)$$

the following fixed pole at $j = 1$:

$$A_0(j, t) = i \frac{a(t)}{j-1} \quad (5)$$

where

$$a(t) = \frac{1}{2(2\pi)^3} \int \frac{dt_1 dt_2}{\lambda^{1/2}(t_1, t_2, t)} \Theta(\lambda) N_a(t_1, t_2, t) N_b(t_1, t_2, t) \quad (6)$$

and N_a and N_b are given by suitable integrals of kinematic factors and π wave functions and the fixed pole residue functions ⁶⁾. By virtue of the fast fall-off of the wave functions in the "masses" of the quarks, we have

$$N_a(t_1, t_2, t) \simeq \beta_a(t_1) \beta_b(t_2) \quad (7)$$

and similarly for N_b . This leads to the approximate factorization of $a(t)$:

$$a(t) \simeq \frac{1}{16\pi^2} \beta_a^2(t_2) \beta_b^2(t_2) \quad (8)$$

As remarked above, the t channel unitarization of the "primeval Pomeron" can be accomplished by the t channel unitarity equations (Fig. 4a)

Fig. 4

$$\frac{1}{2i} \text{Disc}_t F(j, t) = i \rho(t) F(j, t) F^*(j, t) \quad (9)$$

where $\rho(t) = \frac{1}{32\pi^2} \sqrt{(t-4m_\pi^2)/t}$ which is explicitly satisfied by an iteration of the form shown in Fig. 2 and Fig. 4b, i.e.,

$$F(j, t) = k(j, t) + i \rho(t) K(j, t) F(j, t) \quad (10)$$

with $K(j,t)$ a real Born term. For the reasons mentioned we shall follow Gribov⁴⁾ and calculate the effect of the iteration (10) directly in the s channel.

We write the full amplitude $A(j,t)$ in the form :

$$A(j,t) = i a(t) D(j,t) \quad (11),$$

then $D(j,t)$ is given correspondingly by the Lippman-Schwinger type equation

$$D(j,t) = D_0(j,t) + D_0(j,t) V(j,t) D(j,t) \quad (12)$$

where $V(j,t)$ is given by

$$V(j,t) = \frac{3\sigma_{\pi\pi}}{32\pi^3} \int dz z^j \int \frac{dt_1 dt_2}{\lambda^{1/2}(t_1, t_2, t)} \theta(\lambda) \frac{e^{\alpha'_\pi(t_1+t_2-2(z+m_\pi^2)) \log \eta}}{[-t_1+z+m_\pi^2][-t_2+z+m_\pi^2]} \quad (13).$$

Notice that we have introduced a Reggeized pion propagator, and the factor $\log \eta$ corresponds to the rapidity gap generated by the potential, which can be assumed to be small⁷⁾. $\sigma_{\pi\pi} \simeq 2/3 \sigma_{\pi N} \simeq 40 \text{ GeV}^{-2}$ is the $\pi\pi$ cross-section at intermediate energies.

Writing $a = \alpha'_\pi \log \eta$, we obtain

$$D(j,t) = (j - \alpha_P(t))^{-1} \quad (14)$$

with

$$\alpha_P(t) \simeq 1 + \frac{3\sigma_{\pi\pi}}{32\pi^2} \left[\frac{1}{4a} + \frac{t}{4} (1 + \log \sigma^2) + a t^2 \left(\frac{7}{16} + \left(1 + \frac{\sigma^2}{15}\right) \log^2 \sigma^2 \right) \right] \quad (15)$$

where $\sigma^2 = (2am_\pi^2)^{-1}$. Using a value $a = 1.5 \text{ GeV}^{-2}$ we obtain ($\epsilon_0 \simeq 0.06$)

$$\alpha_P(t) \simeq 1.06 + 0.26 t + 0.5 t^2 + \dots \quad (16)$$

which gives a fairly good description of the Pomeron parameters currently favoured by experiments (see Ref. 8)⁹⁾.

The picture emerging from this analysis suggests that the Pomeron is built up from a t channel iteration of a fixed pole at $j = 1$. This is not unlike the picture of Cheng and Wu¹⁰⁾, even though it is derived from a quite different starting point. At low energies ($s \lesssim 30 \text{ GeV}^2$) the diagram in Fig. 1a dominates, thus suggesting that a Chou-Yang description¹¹⁾ of hadron-hadron scattering is not an unreasonable approximation, because of the smallness of ϵ_0 . A pole with intercept greater than 1 (see Eq. 16) is incompatible with s channel unitarity and must therefore be unitarized by s channel iterations; however, as it has been pointed out recently⁸⁾, these iterations need not be

important until very much higher energies. We mention that this picture is at variance with the diffractive or triple Pomeron mechanism which was suggested recently ¹²⁾. A thorough discussion of these results shall be a subject of a forthcoming publication.

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FIGURE CAPTIONS

- Fig. 1 The leading high energy diagrams in hadron-hadron scattering.
 The ladder-like structure represents the "primeval Pomeron".
- Fig. 2 The basic $q\bar{q}$ scattering amplitude (a) and its high energy
 limit (b).
- Fig. 3 The kinematics of the diagram in Fig. 1a.
- Fig. 4 The t channel two-body unitarity equations.