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Author

Rosenzweig, C.

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A SYSTEMATIC LIFTING OF EXCHANGE-DEGENERACY THAT CLARIFIES THE
RELATIONSHIP BETWEEN POMERON, REGGEONS AND SU_3 -SYMMETRY VIOLATION*

C. Rosenzweig and G. F. Chew

Department of Physics and Lawrence Berkeley Laboratory
University of California, Berkeley, California 94720

April 22, 1975

ABSTRACT

The cylinder correction to the planar S matrix splits $I = 0$ from $I = 1$, lifts exchange degeneracy of $I = 0$ states and induces deviations from ideal mixing. All three effects are approximately described by one parameter which gives the shift of the ω intercept below the ρ , the couplings of f , f' , ω , ϕ , the shift of the f above the ρ , and its tendency to become an SU_3 singlet. The splitting apparently decreases as t increases so that the $J = 1^-, 2^+$ particles are nearly ideal (planar) nonets. A smooth connection between $t = 0$ and these physical particles suggests that the phenomenological pomeron is the upward shifted f and thereby explains the small pomeron slope.

Veneziano¹ has proposed a new topological expansion which promises to facilitate the understanding of hadrons. The starting point is a "planar" S matrix possessing nonexotic Regge poles but no Regge cuts and no pomeron. There is exchange-degeneracy between the poles of even and odd charge conjugation ($C = \pm$). The next component of this systematic expansion has the properties of a cylinder and communicates (along its axis) only with states of zero additive quantum numbers; it contains $C = \pm$ but does not maintain exchange degeneracy. The highest lying new Regge trajectory has $C = +$ and at $t = 0$ lies above the highest planar trajectories. It has been supposed that this

trajectory is to be identified as a "bare pomeron" whose properties will be modified by subsequent components of the expansion but which should bear a resemblance to the phenomenological pomeron.

Our investigation² (details will be reported elsewhere) shows that the cylinder shifts planar poles upward in J for $C = +$ and downward for $C = -$ but probably produces no new poles. Identifying our leading trajectory as the pomeron, we find a concrete realization of the "f-dominated pomeron"^{3,4} with SU_3 breaking as proposed by Carlitz, Green, and Zee.³ We go further than these authors by giving, without additional parameters, the shifts of all four leading trajectories (f , ω , f' , ϕ') and the modifications of their couplings, by clarifying the status of the four planar trajectories and by pointing out the connection with the violation of the Iizuka-Okubo-Zweig⁵ rule. Our one parameter (at each value of t) can in principle be calculated from a knowledge of the planar S matrix but we have not yet done so.

Although new poles may arise, together with Regge branch points, in higher-order components of the topological expansion, at the cylinder level the pomeron and f correspond to the same trajectory, in contrast with standard dual resonance models where a new family of reggeon singularities appears at the level of the nonplanar loop.

Lest the reader lose interest at this point, on the grounds that two high-lying but separate positive-charge-conjugation trajectories are unequivocally required by experiment, we call attention to the work of Dash and collaborators.⁶ They showed how a single such trajectory with intercept near 0.85 could satisfy experimental requirements for laboratory energies $\lesssim 30$ GeV. Since terms beyond the cylinder become more important at higher energies, there is no cause

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for despair. On the contrary, reducing the number of trajectories needed to represent moderate-energy data should be welcome.

Our analysis has been carried out in the J plane for the t channel, in a Hilbert space of those (J, t) planar poles communicating with the cylinder. Each pole belongs to a family characterized by a single quark index and definite C . The relevant Regge-behaved planar duality diagram is displayed in Fig. 1a; the dashed line indicating that we are considering the s discontinuity. The cylinder correction corresponds to the sum of 1b, 1c, etc., and may be expressed as the solution of a linear integral equation⁷ whose kernel can in principle be calculated from the residues of the planar poles. We formally write the integral equation for the sum of the planar term and its cylinder corrections, with the external legs amputated, as

$$A = P + PC_1P + PC_1PC_1P + \dots = P(1 - C_1P)^{-1}. \quad (1)$$

P is the planar reggeon propagator, C_1 is the cylinder operator with structure shown in the box of Fig. 1c. The kernel has the same magnitude but opposite sign for $C = +$ or $-$, and at $t = 0$ the even C_1 kernel is positive definite.

Assuming the kernel to be Fredholm it is easy to show that the $I = 0$ planar poles of (1a) are cancelled in the complete sum while the $I \neq 0$ poles are left untouched by the cylinder correction. In a simple approximate calculation we find that new $I = 0$ poles appear at shifted locations but in one-to-one correspondence with the original planar poles.

It is usually supposed that for $t = 0$ and $0 \leq J \lesssim 1$ the planar spectrum contains three poles of each C . For simplicity we confine our attention to these, each of which is associated with a

different quark index. With SU_2 the four planar poles associated with nonstrange quarks are degenerate; we label their common trajectory by $\alpha_0(t)$. The two poles associated with the strange quark are degenerate; these we refer to as $\alpha_3(t)$. If SU_3 symmetry were valid, then $\alpha_3 = \alpha_0$, but it appears that $\alpha_3(t)$ in fact lies substantially lower. As is standard, we break the symmetry only by this mass shift.

We split the Hilbert space according to total isospin, one state carrying $I = 1$ and two carrying $I = 0$. Only the latter are affected by the cylinder, so we use the observed $I = 1$ ρ and A_2 trajectories to fix α_0 and the associated planar residues. The choice of α_3 is less direct but in practice relatively unambiguous. Our concern here is with the position and residues of the four $I = 0$ trajectories f , f' , ω , and ϕ , which emerge from the integral equation, given α_0 , α_3 , and a kernel built from SU_3 -symmetric planar residues. The simplified integral (Eq. 1), specified by the choice

$$P = \begin{pmatrix} 1/(J - \alpha_0) & 0 & 0 \\ 0 & 1/(J - \alpha_0) & 0 \\ 0 & 0 & 1/(J - \alpha_3) \end{pmatrix} \quad C_1 = \pm k \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \quad (2)$$

has the solution

$$A = \sum_x \frac{1}{J - \alpha_x} C^x, \quad (3)$$

where x is the pole label (f , ω , f' , ϕ); C^x is the coupling matrix $C_{ij}^x = g_i^x g_j^x$; and g_i^x the coupling of the x th pole to quark type i .

The two leading output poles, presumed to be the f and ω are located at

$$a_{f,\omega} = \frac{1}{2} \left\{ \alpha_0 + \alpha_3 \pm 3k + \left[(\alpha_0 - \alpha_3 \pm k)^2 + 8k^2 \right]^{1/2} \right\} \quad (4)$$

where the plus (minus) goes with the even (odd) - $C f(\omega)$. The two remaining poles f' and ϕ are also given by Formula (4) but with a negative sign before the square root. In the limit of exact SU_3 the f and ϕ become singlets (see couplings below) and are shifted while the ω and f' are unshifted, being members of octets that do not communicate with the cylinder. Even without SU_3 symmetry the upward shift of the f is larger than the downward shift of the ω , the latter being bounded below by $\frac{1}{3}(\alpha_0 + 2\alpha_3)$ while the former is unbounded above.

For $t \gtrsim 0.5 \text{ GeV}^2$ the small $\rho - \omega$ and $f - A_2$ mass differences allow use of the small k approximation to Formula (4):

$$\alpha_{f,\omega} \approx \alpha_0 \pm 2k, \quad \text{and} \quad \alpha_{f',\phi} = \alpha_3 \pm k.$$

The trajectories are shown in Fig. 2. The coupling matrix for the f is expressed in terms of a mixing angle θ^+ (the rotation toward 0 from the ideal planar mixing angle $\cot^{-1} \sqrt{2}$):

$$\tan 2\theta^+ = \frac{\pm \sqrt{8} k}{\alpha_0 - \alpha_3 \pm k} \quad \text{and} \quad g_{1,2}^f = \frac{\cos \theta^+}{\sqrt{2}}, \quad g_3^f = \sin \theta^+. \quad (5)$$

Couplings for the ω are given by the interchange $\theta^+ \rightarrow \theta^-$, while those for the f', ϕ are given by $\theta^+ \rightarrow \theta^+ + \frac{\pi}{2}$. The connection with the CGZ prescription is exhibited by the equivalent alternative formula

$$\tan \theta^+ = \frac{\alpha_f - \alpha_0}{\sqrt{2}(\alpha_f - \alpha_3)} = - \frac{\sqrt{2}(\alpha_{f'} - \alpha_3)}{\alpha_{f'} - \alpha_0}, \quad (6)$$

with a similar equation for θ^- if $f \rightarrow \omega$. The SU_3 -symmetric limit corresponds to $k \gg \alpha_0 - \alpha_3$ ($\theta^+ = 35^\circ$, $\theta^- = 55^\circ$) while $k \ll \alpha_0 - \alpha_3$ ($\theta^+ = \theta^- = 0$) leaves the original "ideal" mixing of singlet and octet. Physical couplings at $t = 0$ are roughly midway

between these limits. For an illustrative fit it is natural to fix as many parameters as possible at the planar level. The choice $\alpha_0(0) = \alpha_\rho(0) = 0.57$ is straightforward, and we choose $\alpha_3(0) = 0.2$, corresponding to roughly parallel $f' - \phi$ and $\rho - A_2$ (planar) trajectories (see Fig. 2). The remaining parameter, k , is fixed by a characteristic nonplanar effect. Choosing this to be the downward shift of the ω intercept from $\alpha_0(0)$ to $\alpha_\omega(0) = 0.43$, we find, $k = 0.10$, $\theta^- = 23^\circ$, $\theta^+ = 16^\circ$, $\alpha_f = 0.81$, $\alpha_{f'} = 0.26$, $\alpha_\phi = 0.04$, --a substantial deviation from ideal (planar) mixing. The upward shift of the f to an intercept greater than 0.8 allows identification with the "bare pomeron" of Dash. We do not want or need another high-lying trajectory; a second vacuum trajectory with intercept > 0.8 being superfluous.⁶

Following CGZ,³ we may calculate various ratios of total cross sections, e.g., $\sigma_{KN}/\sigma_{\pi N} = 0.70$, $\sigma_{\phi N}/\sigma_{\rho N} = 0.39$ given by our "f-dominated" pomeron couplings. Had we fixed k by requiring α_f to be close to 1 we would have found $\alpha_\omega(0) = 0.39$, $\sigma_{KN}/\sigma_{\pi N} = 0.77$, $\sigma_{\phi N}/\sigma_{\rho N} = 0.53$, showing the relative stability of the parameterization. Our simple model cannot be expected to make predictions of great accuracy, but it qualitatively correlates the various manifestations of nonplanarity and broken SU_3 revealed by Regge pole analysis at moderate energy.

How is the IOZ rule related to the topological expansion? At the planar level this rule is exact, but nonplanar corrections lead to violation. For example, $g_{\phi\pi\pi}/g_{\omega\pi\pi} = \tan \theta^-$ ($t = m_\phi^2$), so to calculate the partial width for ϕ decay into $\pi\pi$ we need $k(t = m_\phi^2)$ as well as $\alpha_0 - \alpha_3 \approx \alpha_\rho - \alpha_\phi$ at $t = m_\phi^2$. An estimate of 0.4 for the latter difference is reasonable (see Fig. 2), while k may be estimated

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as ~ 0.01 from the mass difference between ρ and ω . We arrive at an estimate of θ^- at $t = m_\rho^2$ consistent in order of magnitude with the experimental value of $g_{\rho\pi\pi}$. If the ψ is considered as an SU_4 analog of the ϕ , our model is easily extended to estimate the ψN total cross section as well as the partial width for ψ decay into noncharmed hadrons. These couplings are predicted to be smaller than the corresponding ϕ couplings to the extent that $\alpha_\rho - \alpha_\phi \ll \alpha_\rho - \alpha_\psi$.

Experimental facts require the cylinder shift for $t \gtrsim m_\rho^2$ to be much smaller than at $t = 0$. As already emphasized, the cylinder generator C_1 can in principle be calculated from planar residues⁷ so this sharp variation stands as a challenge to the theory. If the f trajectory is to pass close to 1 (the planar) value at $t = m_\rho^2$, but has a $t = 0$ intercept $1 - \epsilon$, then the slope at $t = 0$ must be $\lesssim \epsilon/m_\rho^2$. Explaining the small slope of the "pomeron" is thus an equivalent, not a separate challenge.

As this note was being prepared we received a preprint discussing some of the points considered here.⁸ These authors discovered the odd-C poles in the cylinder and the extinction of the planar poles. However, they did not consider symmetry breaking and thus did not arrive at our physical interpretation of the cylinder poles.

FOOTNOTES AND REFERENCES

* This work was supported in part by ERDA and in part by NSF Contract No. MPS74-08175-A01.

1. G. Veneziano, Phys. Letters 52B, 220 (1974); Nucl. Phys. B74, 365 (1974).
2. G. F. Chew and C. Rosenzweig, to be published in Nucl. Phys. B.
3. R. Carlitz, M. B. Green, A. Zee, Phys. Rev. D4, 3439 (1974).

4. P. G. O. Freund, H. F. Jones, R. J. Rivers, Phys. Letters 36B, 189 (1971).
5. I. Iizuka, K. Okada, and O. Shito, Progr. Theor. Phys. (Kyoto) 35, 1061 (1966); S. Okubo, Phys. Letters 5, 165 (1963); G. Zweig, unpublished.
6. N. Bali and J. Dash, Phys. Rev. D10, 2102 (1974).
7. Such an equation has recently been studied by Chan H. M., J. E. Paton, Tsou S. T., and Ng S. W., Rutherford Lab., RL-74-149 T99. These authors deal exclusively with the leading trajectory and ignore symmetry breaking effects. They implicitly calculate $k(0)$ and find a value compatible in order of magnitude with the experimental $f - \rho$ splitting.
8. C. Schmid and C. Sorensen, ETH preprint, Zurich.

FIGURE CAPTIONS

1. (a) The planar amplitude communicating with zero additive quantum numbers in t channels.
 (b) The corresponding single-twist cylinder amplitude.
 (c) The double-twist cylinder amplitude, showing the cylinder kernel that generates the entire series.
2. The leading trajectory pattern after the cylinder correction has displaced the $I = 0$ states. The scale of the $t = 0$ splitting shown here is fixed by the choice $\alpha_0 - \alpha_3 = 0.37$, $\alpha_0 - \alpha_\omega = 0.14$.

Fig. 1

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Fig. 2

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