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Author
Chew, G.F.

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G. F. Chew and C. Rosenzweig

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G. F. Chew

Service de Physique Theorique
Centre d'Etudes Nucleaires de Saclay
BP n° 2 - 91190 Gif-sur-Yvette, France

and

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

and

C. Rosenzweig†

Department of Physics
University of Pittsburgh
Pittsburgh, Pa. 15260

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† Present address: Department of Physics, Syracuse University, Syracuse, New York.

ASYMPTOTIC-PLANARITY PREDICTION OF A POMERON-LIKE UNNATURAL-PARITY TRAJECTORY

by

G.F. CHEW and C. ROSENZWEIG

Abstract

The asymptotic-planarity argument that explains the pomeron as a cylinder-shifted f, when applied to unnatural parity, predicts near $t = 0$ a high-lying small-slope H trajectory, with the corresponding $I = 0$, 1^+, $C = -$ meson mass near 1 GeV. H couplings near $t = 0$ will be close to pure SU_3 singlet.

The topological-expansion considerations on the deviation from ideal nonet structure, originally proposed for the leading vector-tensor trajectories$^{1)}$, was subsequently extended to the pseudoscalar-pseudovector mesons$^{2,3,4)}$. In this note we consider the especially interesting implications for the odd-signature unnatural-parity trajectories.

The formalism given in Section VII of Ref. 1) will be employed, with the sole change that the unnatural-parity cylinder coupling $k(t)$ is negative rather than positive. A model-dependent but plausible argument for such a sign inversion has been given by J. Millan$^{5)}$. If $|k(t)|$ is a decreasing function – as expected from the principle of asymptotic planarity$^{1,2)}$– our model predicts a high-intercept small-slope $I=0$, $C=-$ odd-signature trajectory whose first particle manifestation would be a 1^+ meson of mass near 1 GeV commonly called the H meson.

Using the notation of Ref.1), we designate the leading planar trajectory as α_o –corresponding to $\overline{p}p$ and $\overline{n}n$ in quark language. The intercept and slope of α_o are determined by the physical π and B mesons, which undergo no cylinder shift because their isospin is 1. One finds

$$\alpha_o(t) = -.01 + .66t . \tag{1}$$

The I = 0 trajectories η and H are degenerate with π and B in the planar approximation but undergo a cylinder shift - η moving down in J and H up. The trajectory α_3, corresponding to $\lambda\bar{\lambda}$, we take as parallel to α_o with a downward J displacement of 0.3[6]. This displacement is implied by the masses of K and Q[7], together with the planar rule of equal-spacing between $\bar{p}p$, $\bar{p}\lambda$ and $\bar{\lambda}\lambda$ trajectories[8]. In the simple planar approximation the η' and H' trajectories lie on α_3, but both undergo cylinder shifts, η' moving down and H' up.

It is safest to begin the analysis with the measured η' mass. This determines the value of t (.92 GeV^2) at which $\alpha_{\eta'} = 0$, a point where $\alpha_o = .6$ and $\alpha_3 = .3$. From the formula[1]

$$\alpha_{\eta,\eta'} = \frac{1}{2} \left\{ \alpha_o + \alpha_3 + 3k \pm \left[(\alpha_o - \alpha_3 + k)^2 + 8k^2 \right]^{1/2} \right\} , \qquad (1)$$

we may then deduce the cylinder strength at this value of t to be $k(m^2_{\eta'}) \approx -0.15$. At the same time from the formula

$$\tan 2\theta^+ = \frac{\sqrt{8}\, k}{\alpha_o - \alpha_3 + k} , \qquad (2)$$

one finds that the η' wave function has been rotated away from ideal $\lambda\bar{\lambda}$ by an angle $\theta^+(m^2_{\eta'}) \approx -35°$. The minus sign means that the cylinder has shifted η' closer to an SU$_3$ singlet - further from an octet (pure singlet corresponds to $\theta^+ = -55°$).

If one attempts to use the measured η mass to determine the cylinder strength at $t = m^2_\eta$ from formula (1) or the inverse formula

$$k(m^2_\eta) = \frac{\alpha_o(m^2_\eta) \times \alpha_3(m^2_\eta)}{\alpha_o(m^2_\eta) + 2\alpha_3(m^2_\eta)} , \qquad (3)$$

one finds a large uncertainty, because the denominator of formula (3) nearly vanishes. Uncritical use of our prescription for α_o and α_3 in formula (3) leads to a cylinder coupling at $t = m^2_\eta$ that is about three times larger in magnitude than at $t = m^2_{\eta'}$, but a constant value (-.15) for k(t) would correspond to m^2_η only 20% smaller than the observed value. The possibility of a 20% error in formulas (1) and (3) cannot be ignored. We have in the first place neglected higher terms in the topological expansion (handles) which can produce trajectory shifts of order 0.1, as indicated by the experimental ρ-A_2 intercept difference. Equations (1) and (3) are furthermore based on the assumption of perfect SU_3 symmetry for the cylinder. We therefore cannot conclusively infer from the η and η' masses that $|k(t)|$ grows as t diminishes - the behaviour predicted by asymptotic planarity. Are there any other experimental facts relevant to asymptotic planarity for unnatural parity ?

In the models of Refs.(3 and 4) where the decays $\psi \to \gamma+\eta$ or η' proceed through the charm content of the pseudoscalar mesons, the ratio $\frac{\psi \to \eta' \gamma}{\psi \to \eta \gamma}$ is a sensitive test of asymptotic planarity. This ratio would be ≈ 25 if $k(m_\eta^2) = k(m_{\eta'}^2)$ (assuming ψ is an SU_3 singlet) and is reduced to 5 if $k(m_\eta^2) \approx 2k(m_{\eta'}^2)$. The experimental data favor the latter alternative. Further support comes from the comparison of the cross sections $\sigma(K^- p \to \eta\Lambda) + \sigma(K^- p \to \eta'\Lambda)$ with $\sigma(K^- p \to \pi^o\Lambda) + \sigma(\pi^- p \to K^o \Lambda)$. These two quantities are equal$^{9)}$ if $\theta^+(m_{\eta'}^2) = \theta^+(m_\eta^2)$ while the latter is larger if $\theta^+(m_{\eta'}^2) < \theta^+(m_\eta^2)$ (asymptotic planarity). Low energy data$^{10)}$ show such an inequality, although the observed effect is much larger than one expects in a Regge representation for the modest differences in θ^+ predicted by our model. It will be interesting to see if the effect persists at an appropriate level when simple Regge behaviour sets in for all four reactions.

For leading natural parity trajectories the rate of change of cylinder strength for $|t| < 1$ GeV^2 is roughly exponential and characterized by an interval $t_c \approx 0.5$ GeV^2 . It was pointed out in Ref.2) that t_c for unnatural parity is likely to be larger, and in the remainder of this note we consider the illustrative range of possibilities 2.0 GeV$^2 < t_c < \infty$.

The formula for α_H and $\alpha_{H'}$, the odd charge-conjugation (odd-signature) I = 0 trajectories, is the same as (1) but with k replaced by -k. Similarly the mixing angle θ^- is obtained by inserting a minus sign in front of k in formula (2). Figure (1) shows the predicted trajectories for $k(m_{\eta'}^2) = -0.15$ with $t_c = 2.0$ GeV^2 and $t_c = \infty$, while figure (2) shows the corresponding mixing angles θ^- . Note that the H trajectory passes through $J = 1$ near $t = m_{\eta'}^2$, where the uncertainty about t_c is unimportant, so the predicted value of the I=0 , 1^+, C = − meson mass is almost unambiguous.

For t near zero the value of t_c is important, but a relatively high intercept and small slope for the H trajectory cannot be avoided, the t=0 mixing angle θ^+ being close to the pure SU_3 singlet value of +35° . The H trajectory thus shows many of the same qualitative characteristics as the pomeron. We remind the reader that because of the particular way in which we implemented the model of ref.1) 20% effects on the shift of $\alpha_\eta(m_\eta^2)$ can cause a change in the shift of $\alpha_H(o)$ of almost an order of magnitude. We thus treat the extreme values of $\alpha_H(o)$ with great caution, but expect the qualitative features to be true. In particular we expect $\alpha_H(o) - \alpha_\pi(o) \geq \alpha_\pi(o) - \alpha_{\eta'}(o)$.

Current experiments do not demand an H trajectory with the properties we predict. The data are also not sufficiently accurate to rule out our conjecture.11) Careful experimental efforts to establish or disprove the existence of such a distinctive Regge singularity are called for.

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FIGURE CAPTIONS

Fig.1 : The predicted H and H' trajectories.There is negligible dependence of the H' trajectory on the parameter t_c .

Fig.2 : The predicted H-H' mixing angle that measures the deviation from ideal mixing. According to asymptotic planarity θ^- approaches zero as $t \to +\infty$ and approaches -35° as $t \to -\infty$.

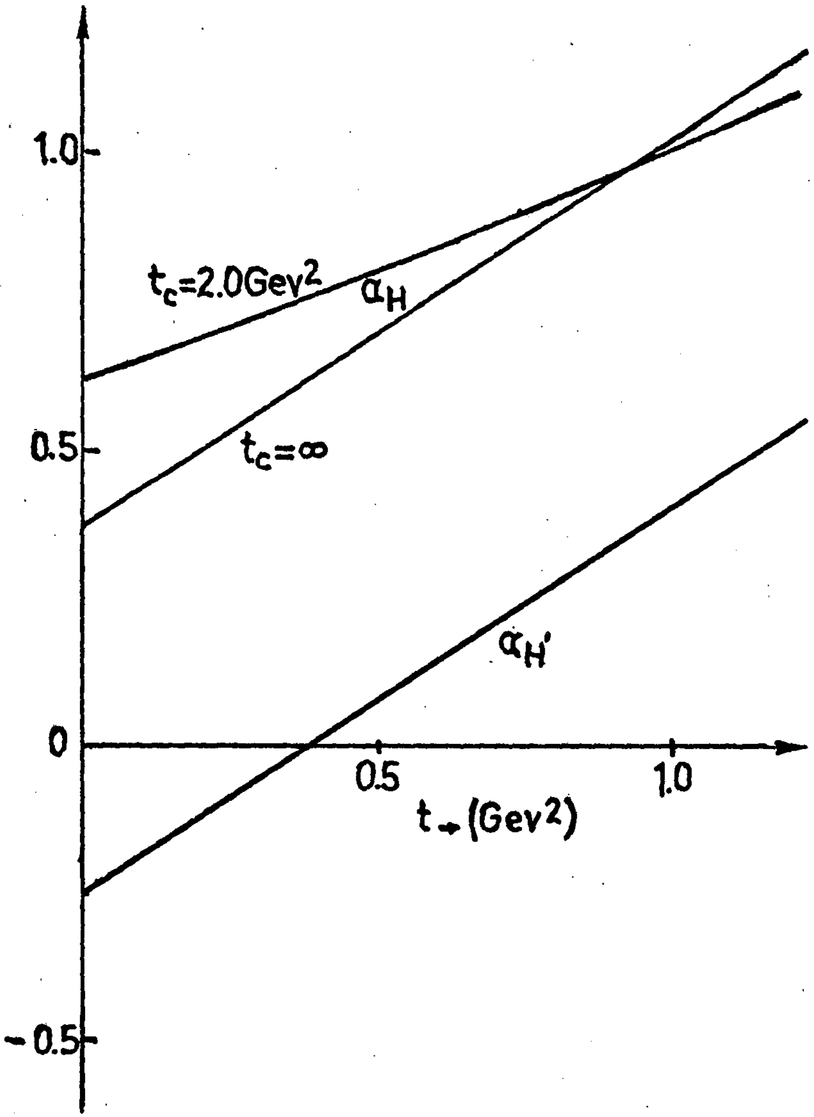
1.0
0.5
0
-0.5
0.5
1.0
t_c=2.0Gev^2
α_H
$t_c=\infty$
$\alpha_{H'}$
t → (Gev^2)

Fig. 1

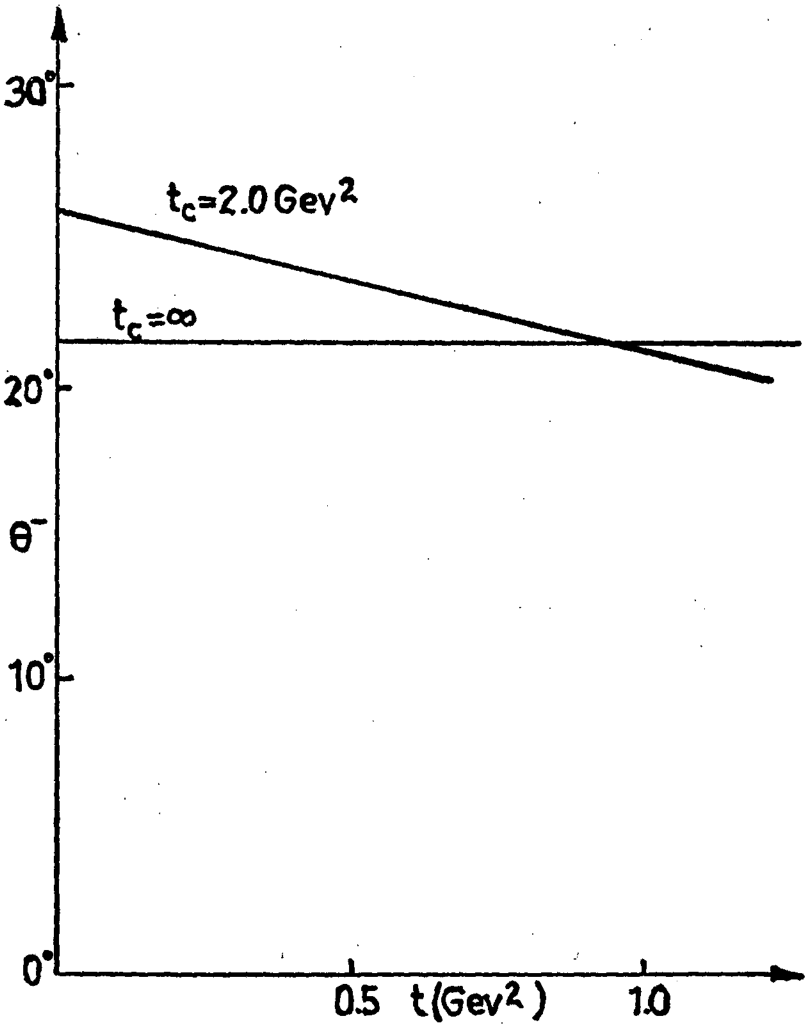
30°
20°
10°
0°
θ⁻
t_c=2.0 Gev^2
$t_c=\infty$
0.5
t (Gev^2)
1.0

Fig. 2

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720