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MASTER

Duality Diagrams with Exotic t-channel Exchanges
in Meson-Baryon Scattering.*

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We show that using duality diagrams with slightly modified rules that allow exotic t-channel exchanges in $MB \rightarrow MB$ scattering, the main discrepancies between experimental data and the predictions of the usual Regge pole model with duality and no exotic s-channel resonances are removed. On the other hand all the successful predictions of the usual model and a simple picture of exchange degenerate Regge trajectories remains unchanged.

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The existence of exotic meson resonances made out of two quark-antiquark pairs has been suggested¹ from the study of baryon-antibaryon scattering and duality. Recently, it has been shown² that exotic t-channel exchanges are required by multiperipheral models. There is also mounting experimental evidence³ for exotic exchanges.

In the following note it will be shown that all major failures of the Regge pole model and two-component concept of duality⁴ in the meson-baryon scattering can be cured if exotic t-channel exchanges are allowed in the MB $\rightarrow$ MB processes.⁵

The Regge pole model together with the two-component concept of duality is quite successful in correlating many features of hadron reactions at high energy. If one supplements the scheme with the quark model motivated assumption of no exotic states in the s-channel the beautiful predictions of the exchange degeneracy of $\rho - A_2$ and $K^* - K^{**}$ Regge trajectories as well as the constancy of the K^+p and K^+n total cross sections follow.

There is no doubt that experimentally measured K^+p and K^+n total cross sections agree with the above prediction. The $\rho - A_2$ and $K^* - K^{**}$ exchange degeneracy is supported for positive t by the masses of the ρ , A_2 , K^* and K^{**} resonances assuming that they lie on approximately linear trajectories with the slope of about $1(\text{GeV}/c)^{-2}$. Furthermore the $\rho - A_2$ exchange degeneracy seems to be confirmed by the equality of the $K^+n \rightarrow K^0p$ and $K^-p \rightarrow \bar{K}^0n$ differential cross sections⁶ at 5.5 as well as at 12 GeV/c.

On the other hand, if the $K^* - K^{**}$ exchange degeneracy is combined with factorization the disastrous prediction of the equality of the $K^-n \rightarrow \Lambda\pi^-$ and $\pi^-p \rightarrow \Lambda K^0$; $\pi^+p \rightarrow K^+\Sigma^+$ and $K^-p \rightarrow \pi^-\Sigma^+$ differential cross sections and zero polarization for all four reactions (from the strong form

of exchange degeneracy) emerges. If we add to that the predicted zero polarization in $\pi^- p \rightarrow \pi^0 n$ and $\pi^- p \rightarrow \eta n$ we have all the major failures of the discussed scheme for the $MB \rightarrow MB$ scattering.

One can argue that all failures are due to the Regge-pole model alone and that the cuts or at least complex conjugate poles should be introduced. However, unless we have additional rules governing the contribution of Regge cuts most of the simplicity and predictive power of the Regge pole model is lost. Complex conjugate poles can explain nonzero polarization in πN CEX scattering⁷ and nonequality of the differential cross sections in the hypercharge exchange reactions, but then there is no reason why $K^+ n \rightarrow K^0 p$ and $K^- p \rightarrow \bar{K}^0 n$ differential cross sections should be equal.⁸ Moreover to give nonzero polarization in the hypercharge exchange reactions the K^* and K^{**} trajectories cannot be exchange degenerate.

In the following we would like to point out, in the framework of duality diagrams, how to include additional contributions that will remedy all the major failures of the simple pole model while still retaining all the successful predictions and simplicity of the model. We shall show that this can be achieved if we relax the usual assumption of no exotic states to allow exotic t-channel exchanges (exchanged of two quark-antiquark pairs (which do not necessarily have exotic quantum numbers). Note that presence of exotic t-channel exchanges can still be consistent with no exotic s-channel resonances. For example, we can have double exchange of non-exotic mesons or Regge cuts.

To visualize how the above discrepancies will be removed by allowing exotic t-channel exchanges we will proceed using the quark model duality diagrams.⁹ The basic rules of drawing a legal diagram have to be slightly modified. We require that for a legal diagram (for which the imaginary

part does not have to vanish): i) all external and s-channel (but not t-channel) internal hadrons are either three quark or quark-antiquark states, ii) every quark line retains its identity and iii) the two ends of any quark line must belong to different external particles. With this set of rules we find that for $K^+n \rightarrow K^0p$ and $K^-p \rightarrow \bar{K}^0n$ scattering we can draw only the usual duality diagrams (Fig. 1a, 1b). The reader can convince himself that it is impossible to construct any diagram with exotic t-channel for the above reactions. Duality then leads to the $\sigma - A_2$ exchange degeneracy and to the equality of the corresponding differential cross sections, which is in good agreement with experimental data.⁶

The same situation occurs in the $K^+\pi^+ \rightarrow \pi^+K^+$ scattering and leads to the exchange degeneracy between the K^* and K^{**} trajectories.

The situation is different in the meson-nucleon hypercharge exchange reactions. Figure 2 shows the quark model diagrams for $K^-n \rightarrow \Lambda\pi^-$ and $\pi^-p \rightarrow \Lambda K^0$ scattering. Figure 2a has exotic¹⁰ intermediate s-channel and therefore the imaginary part of the amplitude corresponding to this diagram has to vanish (K^* and K^{**} exchange degeneracy). However, the second diagram (2b) is a legal diagram according to our rules and the hypothesis that exotic t-channel exchanges are allowed. Because we have nonexotic s-channel the imaginary part of the amplitude for $K^-n \rightarrow \Lambda\pi^-$ does not have to vanish and thus polarization will be in general nonzero. The corresponding diagrams for $\pi^-p \rightarrow \Lambda K^0$ are 2c and 2d. The presence of the exotic exchanges in these reactions will destroy the equality¹¹ of the corresponding differential cross sections.¹² Similar situation occurs for $K^-p \rightarrow \pi^-\Sigma^+$ and $\pi^+p \rightarrow K^+\Sigma^+$ reactions.

If we turn to the $\pi^-p \rightarrow \pi^0n$ we find again that exotic t-channel

exchanges will contribute (Figs. 3a, 3b) and produce additional contribution to the amplitude with nonzero phase. Consequently the interference between the ρ contribution and exotic exchange contribution results in nonzero polarization.

Finally one finds that exotic exchanges do not contribute to the elastic K^+p and K^+n scattering (Figs. 3c, 3d) and therefore the corresponding total cross sections remain constant.

We have found that exotic t-channel exchanges are necessary to remove the discrepancy between experimental results and the Regge model and duality in the $MB \rightarrow MB$ scattering (nonzero polarization in the πN CEX and KN HEX and unequal differential cross sections for KN HEX reactions¹³). On the other hand all the successes of the original scheme as well as the simple picture of exchange degeneracy survives.

If one allows exotic t-channel exchanges also in the baryon-baryon scattering, nonzero polarization in the charge exchange reaction $pn \rightarrow np$ can be explained (in this case it is necessary to assume that exotic t-channel exchanges together with Pomeron exchange are dual to the background term in the s-channel). Then the pp and pn total cross sections will get additional contribution from exotic exchange and they become energy dependent, in agreement with experimental data.

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5. We denote by M a pseudoscalar meson and by B a $1/2^+$ baryon.
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10. Exotic in the sense that the baryonic state is not a three quark state.
11. Even if the differential cross sections of processes where only exotic exchanges can contribute are only 4% of that due to nonexotic exchanges, the exotic contribution can still produce the ration 2:1 for the differential cross sections for reactions related by the $s \rightarrow u$ crossing if both exotic and nonexotic exchanges can contribute.
12. We don't want to speculate whether our exotic t-channel exchanges correspond to the exchange of exotic meson or simply to the two particle exchange or to the cut. However, if they correspond to the cuts, it

is plausible to assume that the contributing cut is the Regge-Regge cut rather than Regge-Pomeranchuk cut even though the quantum numbers may be nonexotic.

13. For experimental data on the hypercharge exchange reactions see K. W. Lai and J. Louie, Nucl. Phys. B19, 205 (1970) and references given there.

Figure Captions

- Fig. 1: Only diagrams with nonexotic t-channel can be constructed for the $K^+n \rightarrow K^0p$, $K^-p \rightarrow \bar{K}^0n$ and $K^+\pi^+ \rightarrow \pi^+K^+$ scattering.
- Fig. 2: The scattering amplitudes for $K^-n \rightarrow \Lambda\pi^-$ and $\pi^-p \rightarrow \Lambda K^0$ get additional contributions from the diagrams 2b and 2d with exotic t-channel.
- Fig. 3: The $\pi^-p \rightarrow \pi^0n$ scattering amplitude gets the contribution from the ρ exchange (3a) and exotic exchange (3b) with nonzero imaginary part. Consequently the polarization will be nonzero. Only illegal duality diagrams (3c) and (3d) can be constructed for $K^+p \rightarrow K^+p$ and $K^+n \rightarrow K^+n$ scattering.

Fig. 1

(2a)

(2c)

(2b)

(2d)

Fig. 2

(3a)

(3c)

(3b)

(3d)

Fig. 3