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HIGHER MULTIPLETS OF MESON AND BARYON RESONANCES

A CONSEQUENCE OF RESONANCE SATURATION HYPOTHESIS

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A B S T R A C T

Meson resonances with exotic quantum numbers, predicted by Rosner under the assumption of local resonance saturation, are shown to follow from the much less stringent assumption of global resonance saturation. The same hypothesis, applied to the scattering of baryons against these mesons, is then shown to imply the existence of baryon resonances with exotic quantum numbers as well. And the latter, in turn, seems to imply meson resonances, with still more exotic quantum numbers.

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Various elastic scattering processes, involving the pseudo-scalar meson octet M , the baryon octet B and the decuplet D , have recently been studied by Rosner ¹⁾ under the assumption of local resonance saturation. This assumption amounts to equating the non-Pomeron Regge contribution to that of a local average over the direct channel resonances in the Regge energy region. For the meson-meson and meson-baryon scattering processes this assumption is consistent with the occurrence of meson resonances only in the representations 1 and 8, and baryon resonances only in the representations 1, 8 and 10 of $SU(3)$. However, for the baryon-antibaryon scattering processes this requires strong resonances in the 10, $\overline{10}$ and 27 dimensional representations, if strong dibaryon resonances are assumed to be absent.

We start here by analysing the same problem under the less restrictive assumption of global resonance saturation ^{2),3)}, which we feel necessary because of the following circumstances. In some cases the Regge contribution has been demonstrated to average the direct channel resonance contributions only globally ⁴⁾, and even in the case of charge exchange π -N scattering, where an approximate local equivalence between the Regge and direct channel resonance contributions has been demonstrated ⁵⁾, this has been done only for resonances below the Regge energy region. Moreover, the presence or absence of resonances in specific channels, as predicted by the local saturation hypothesis ¹⁾, applies only to resonances in the Regge energy range, whereas the same conclusions obtained from the global saturation hypothesis apply to resonances in the entire sub-Regge energy region. In this sense the present result should be distinct from the prediction of Ref. 1), and physically more interesting.

For our purpose it suffices to consider only one helicity amplitude T corresponding to zero net helicities in the t -channel. The global saturation hypothesis implies

$$\int_0^N \left[\text{Im } T_{ab \rightarrow cd}^R - \text{Im } T_{a\bar{d} \rightarrow c\bar{b}}^R \right] d\nu = 2 \sum_i \beta_i \frac{N^{\alpha_i+1}}{\alpha_i+1} \quad (1)$$

and

$$\int_0^N [Im T_{ab \rightarrow cd}^R + Im T_{a\bar{d} \rightarrow c\bar{b}}^R] \nu d\nu = 2 \sum_j \beta_j \frac{N^{\alpha_j+2}}{\alpha_j+2} \quad (2)$$

where $ab \rightarrow cd$ and $a\bar{d} \rightarrow c\bar{b}$ refer to scatterings in the s and u channels respectively and the superscript R stands for resonance contribution. The summation on i is over the t -channel Regge poles with odd signature and that on j is over the t -channel Regge poles with even signature, besides the Pomeron, as suggested by Harari ³⁾. Thus, if the s and u channels are both free of resonances (at least up to the Regge energy region N), then the contributions of the degenerate vector nonet trajectories and the degenerate tensor nonet trajectories in the t -channel should both vanish ⁶⁾. In the actual situation of degeneracy breaking, the vanishing should occur separately for φ and f' as well as for the combinations (K^*, ρ, ω) and (K^{**}, A_2, f) . Of course, the global saturation in its strict sense does still not give separate vanishing for the octet and the non-degenerate singlet trajectories. In this sense, the decoupling requirement of φ and f' from non-strange baryons may be considered as an input assumption ⁷⁾.

On assuming the meson resonances to occur only in singlets and octets and baryon resonances to occur only in singlets, octets and decuplets, we see that whereas no MM or MB scattering process can be free from resonances in both s and u channels, there exist two such processes for the MD case, namely the $K^0 \Delta^{++}$ and $\pi^+ \Omega^-$ elastic scatterings. The vanishing of φ and f' contributions here, is equivalent to the usual nonet requirements of φ and f' decoupling from non-strange baryons and f' decoupling from pions as well. Then the cancellation between the ρ and ω contributions for $K^0 \Delta^{++}$ scattering is guaranteed by the $SU(3)$ coupling relation ⁸⁾ for arbitrary $\omega - \rho$ mixing angle. The cancellation between A_2 and f contributions implies

$$(2 - \cot^2 \theta) g_8 G_8 = 0 \quad (3)$$

where g_8 and G_8 are the coupling of the tensor meson octet with the pseudoscalar meson octets and baryon decuplets respectively, and θ is the $f-f'$ mixing angle⁹⁾. This condition is obviously satisfied for the usual mixing angle $\tan \theta = 1/\sqrt{2}$. This value of θ also guarantees the decoupling of f' from Ω^- so that none of the vector and tensor meson can contribute to the $\pi^+\Omega^-$ scattering.

We now consider the $D\bar{D}$, $D\bar{B}$ and $B\bar{B}$ scattering processes under the assumption of no strong dibaryon resonances¹⁰⁾. The net vector meson (or equivalently tensor meson) contributions to the process $\Delta^{++}\bar{\Omega}^+ \rightarrow \Delta^{++}\bar{\Omega}^+$, belonging to the representation 64, can be written as⁸⁾

$$(2 - \cot^2 \theta) G_8^2 = 0 \quad (4)$$

which again vanishes for the mixing angle $\tan \theta = 1/\sqrt{2}$. This implies the absence of $D\bar{D}$ resonances in the 64 dimensional representation. On the other hand, the process $\Delta^{++}\bar{\Xi}^{*+} \rightarrow \Delta^{++}\bar{\Xi}^{*0}$, involving a mixture of the 64 and 27 dimensional representations, has non-vanishing contributions from the vector and tensor nonets, since only the ρ^+ and A_2^+ exchanges can contribute. Therefore it seems to imply the existence of $D\bar{D}$ resonances in the 27 dimensional representation. For a $\bar{B}D$ scattering process in the 35 dimensional representation, the nonet contribution can be seen to vanish for any value of α ($= F/F+D$). On the other hand, for a $\bar{B}D$ scattering process, belonging to the representation 27, the nonet contribution vanishes only for $\alpha = \frac{1}{2}$ and for a process belonging to the representation 10, it vanishes only for $\alpha = \frac{2}{3}$. Thus, for no value of α can the representations 27 and 10 be both free of resonances. The conventional value of $\alpha = 1$ implies resonances in both these representations. Similarly for the $B\bar{B}$ scattering process, the t-channel vector and tensor couplings with $\alpha = 1$ are seen to imply resonances in 10, $\bar{10}$ and 27 dimensional representations.

Thus, the saturation hypothesis applied to the baryon-antibaryon scattering implies meson resonances M' belonging to the representations 10 , $\overline{10}$ and 27 . Moreover, the same hypothesis, when applied to the scattering of these new mesons against baryons, is seen to imply the presence of strong baryon resonances outside the representations 1 , 8 and 10 , unless the meson trajectories all decouple from M' for all t ¹¹⁾. As an illustration we consider the process $\Delta^+ M'_{10}(-1\frac{1}{2}\frac{1}{2}) \rightarrow \Delta^{++} M'_{10}(-1\frac{1}{2}-1)$, where the quantities in the brackets stand for the hypercharge, isospin I and I_3 of the new meson belonging to a decuplet. This being a charge exchange reaction must have finite contributions from the vector and tensor nonets in the t -channel. But the s -channel (being a 10 - 10 scattering process) is a mixture of the representations 35 , 28 , 27 and $\overline{10}$ whereas the u -channel contains the representations 64 and 27 . Therefore, eqs. (1) and (2) imply baryon resonances in some of the above representations. We could further consider the scattering of these exotic baryon resonances. It would imply more exotic meson resonances. For instance, the hypercharge exchange scattering of Σ^- against a $Y = 2$ baryon would imply mesonic resonances in the u -channel with $Y = 3$. It seems to be unlikely that any closed set of meson and baryon resonances turns out to be a consistent solution to resonance saturation of finite-energy-sum-rules.

In summary, the global resonance saturation hypothesis, when applied to baryon-antibaryon scattering, leads to an expansion of the conventional meson and baryon spectra unless there are strong dibaryon resonances. This does not necessarily contradict our earlier result on meson-baryon scattering. It should, however, be necessary to postulate a decoupling of these new resonances from such channels which show no structure experimentally up to very high energy.

We may also mention two alternative possibilities which seem to be suggested by the fact that the resonance saturation hypothesis seems to work for meson-baryon scattering with no extra resonances. One possibility is to invoke strong dibaryon resonances, of course outside the nucleon-nucleon channel (i.e., outside the $\overline{10}$

and 27 representations). In this way it is possible to do without higher meson multiplets in baryon-antibaryon scattering. But on the other hand, it has the unpleasant feature of bringing in very high dibaryon multiplets. For the $D\bar{D}$ scattering, for instance, this would require dibaryon resonances in the u-channel belonging to the 28 and 35 dimensional representations. The other possibility is to allow significant non-resonant contributions for the baryon-antibaryon scattering, unlike the meson-baryon scattering case. Then the observed flatness of nucleon-nucleon cross sections, which has been explained by the more restrictive assumption of local resonance saturation ³⁾, has to be attributed to alternative mechanisms, as the one suggested by Henzi and Van Hove on the basis of annihilation channels ¹²⁾.

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FOOTNOTES AND REFERENCES

- 1) J.L. Rosner, Phys.Rev.Letters 21, 950 (1968).
- 2) By global resonance saturation we mean resonance saturation in the usual sense of the finite energy sum rule as given in Eqs. (1) and (2). In Harari's model (see Ref. 3)) the resonance saturation of the Regge pole contributions is postulated in this sense only, although he has used the more restrictive assumption of local saturation in order to obtain exchange degeneracy.
- 3) H. Harari, Phys.Rev.Letters 20, 1395 (1968).
- 4) F. Gilman, H. Harari and Y. Zarmi, Phys.Rev.Letters 21, 689 (1968).
- 5) C. Schmid, Phys.Rev.Letters 20, 689 (1968).
- 6) On the other hand, whenever a single channel is free of resonances in the Regge energy region, the local saturation hypothesis would give a relation amongst the t-channel Regge contributions involving, of course, both vector and tensor trajectories.
- 7) This assumption is, however, irrelevant for the charge and hypercharge exchange scattering processes considered below. Such processes alone are sufficient to predict meson resonances in the combinations of representations (10, 27); (10, 35); (27, 35) and (27, 64), but not enough to pin them down to specific representations.
- 8) P. McNamee and Frank Chilton, Rev.Mod.Phys. 36, 1005 (1964).
- 9) This mixing angle has earlier been obtained from the local saturation hypothesis. See C.B. Chiu and J. Finkelstein, Phys.Letters 27B, 510 (1968).
- 10) By this, we mean dibaryon resonances with couplings as strong as the vector and tensor meson couplings on the right-hand side of eqs. (1) and (2).

- 11) However, the same hypothesis, when applied to MM' or $M'M'$ scattering, does not lead to any higher meson multiplets.
- 12) R. Henzi, Nuovo Cimento 52A, 772 (1967);
L. Van Hove, Particle Interactions at High Energy, ed. by
T.W. Preist and L.L.J. Vick (Oliver & Boyd, Edinburgh and
London), p.63 (1966).