tailed work is needed to confirm this impression.

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REMARKS ON THE MULTIPLET STRUCTURE OF STRONG INTERACTION SYMMETRY*

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In the usual group-theoretic discussion of strong interaction symmetry, one starts with a given symmetry group and then proceeds to examine what kinds of supermultiplets are predicted by the group under consideration. For instance, in the so-called "eightfold way,"[1] we start with the group SU(3) together with the requirement $|p-q| = 0, 3, 6, \cdots$, where p and q refer to the numbers of the upper and lower indices of an irreducible tensorial representation; we then obtain the result that the strongly interacting states must be grouped into supermultiplets of dimensionalities 1, 8, 10, 27, etc., with definite isospin and hypercharge contents. Since what we directly observe in our laboratory are not the structure constants of a Lie algebra but rather the supermultiplets themselves, it is of some interest to examine the converse problem of inferring the correct symmetry group once the patterns of supermultiplets are given. The purpose of this Letter is to show how this problem may be solved in some simple cases using specific illustrative examples. We also comment on the recent work of Capps[2] who claims to have derived the SU(3) symmetry from dispersion-theoretic considerations.

First, for orientation purposes, let us consider the very trivial and familiar case of the Yukawa-type coupling of the (π^+, π^-, π^0) triplet to the (p,n) doublet. We do assume electric charge conservation and baryon number (or nucleon number) conservation, but let us pretend that we are ignorant of the $\vec{\tau}\cdot\vec{\pi}$ structure of the interaction or of the rule for adding angular momenta. Before we switch on the pion-nucleon interaction, the charged and the neutral pions as well as the p and n are assumed to be degenerate. It is of interest to note that we can actually "derive" the consequences of charge independence of the $\bar{N}N\pi$ vertex merely by demanding that the degeneracies persist in the presence of the pion-nucleon interaction. To see this, we just require that the self-energies of the p and the n (the $\pi^\pm$ and the π^0) be equal; by considering second-order graphs, we have

$$\delta m_p = \delta m_n \Rightarrow G^2(\pi^+\bar{p}n) + G^2(\pi^0\bar{p}p) = G^2(\pi^0\bar{n}n) + G^2(\pi^+\bar{p}n),$$

$$\delta m_{\pi^+}^2 = \delta m_{\pi^0}^2 \Rightarrow G^2(\pi^+\bar{p}p) = G^2(\pi^0\bar{p}p) + G^2(\pi^0\bar{n}n),$$

and hence the famous relation

$$G^2(\pi^+\bar{p}n) = 2G^2(\pi^0\bar{p}p) = 2G^2(\pi^0\bar{n}n).$$

Similar considerations based on fourth-order graphs lead to one additional condition,

$$G(\pi^0\bar{p}p) = -G(\pi^0\bar{n}n).$$

In other words, the very existence of the degenerate pion multiplet and the degenerate nucleon multiplet in the presence of their mutual interactions demands that the $\bar{N}N\pi$ vertex satisfy the usual requirements that follow from the charge-independent $\vec{\tau}\cdot\vec{\pi}$ interaction.

We now consider the the Yukawa-type interactions of the pions with the eight baryons, $p, n, \Lambda, \Sigma^{\pm,0}, \Xi^{-,0}$. This time we do assume charge independence and try to obtain relations among the four pion-baryon coupling constants. Suppose the eight baryons were degenerate before we switch on the pion-baryon couplings. The requirement that the degeneracy of the baryons persist in the presence of the pion-baryon interactions immediately yields the relation

$$g_{\pi N}^2 = g_{\pi\Lambda}^2 = g_{\pi\Sigma}^2 = g_{\pi\Xi}^2.$$

As is well known, this relation is required by global symmetry.[3,4] (The g's are defined as in reference 3.) From this point of view, we may understand why global symmetry was considered to be a natural scheme in the good old days when there were no other mesons except the pions, and the K mesons and the K-meson couplings were believed to be "weak."

As our last (and somewhat less trivial) example, we consider the linear interactions of the vector mesons ($\varphi^0, \rho^{\pm,0}, M^{+,0}, M^-, \overline{M}^0$) to the vector currents formed bilinearly by the pseudoscalar mesons ($\eta^0, \pi^{\pm,0}, K^{+,0}, K^-, \overline{K}^0$). Again we assume that in the absence of interactions, the pseudoscalar mesons (vector mesons) are degenerate. The requirement that the lowest order self-energies of the pseudoscalar mesons be equal in the presence of interactions leads to[5]

$$2g_{\rho\pi\pi}^2 + \tfrac{4}{3}g_{MK\pi}^2 = \tfrac{1}{2}g_{\varphi KK}^2 + \tfrac{3}{2}g_{\rho KK}^2 + g_{MK\pi}^2 + g_{MK\eta}^2 = 4g_{MK\eta}^2.$$

Similarly, from the equality of the vector-meson self-energies (or from the equalities of the total decay widths in case of unstable vector mesons), we obtain

$$g_{\rho\pi\pi}^2 + g_{\rho KK}^2 = g_{MK\pi}^2 + g_{MK\eta}^2 = g_{\varphi KK}^2.$$

We have four relations among the five coupling constants. Solving for the ratios, we get

$$g_{\rho\pi\pi}^2 : g_{\rho KK}^2 : g_{MK\pi}^2 : g_{MK\eta}^2 : g_{\varphi KK}^2 = \tfrac{4}{3} : \tfrac{2}{3} : 1 : 1 : 2. \quad (1)$$

By considering fourth-order graphs, we obtain one additional condition,

$$g_{\rho\pi\pi} g_{\rho KK} > 0. \quad (2)$$

The ratios given by (1) together with relation (2) correspond exactly to the coupling constant relations that follow from unitary symmetry.[1,6]

In reference 2, Capps, like us, starts with an octet of degenerate pseudoscalar mesons and an octet of degenerate vector mesons. He then asks: What kind of coupling constant relations are implied by the requirement that the vector-meson octet and the pseudoscalar-meson octet support themselves in a self-consistent way by means of a bootstrap mechanism of the Zachariasen-Zemach[7] type? The answer he obtains (using an approximate multichannel N/D method) is that the coupling constants must satisfy the unitary symmetry relations (1) and (2). Throughout his self-consistent calculations, Capps assumes that not only the pseudoscalar mesons but also the vector mesons that can be exchanged between a pair of pseudoscalar mesons remain degenerate.

We have shown that a very simple perturbation-theoretic consideration based on the requirement that the mass degeneracies persist both for the pseudoscalar octet and for the vector octet in the presence of interactions immediately leads to the unitary symmetry relations (1) and (2). It is then of no surprise that much more sophisticated dynamical calculations (such as the approach of Capps[2]) also lead to (1) and (2), provided we make certain that the mass differences within the supermultiplets are kept equal to zero at each stage of the calculations. It is for this reason entirely misleading to assert that unitary symmetry is "predicted by the bootstrap technique." Relations (1) and (2) have nothing to do with dispersion theory.

As seen from our third example and also from Capps' work, a mutual interaction between the degenerate vector-meson octet and the degenerate pseudoscalar-meson octet (with isospin and hypercharge contents $Y=0$, $T=1, 0$; $Y=\pm 1, T=\frac{1}{2}$) is compatible only with the SU(3) symmetry. One may naturally ask: Is this result surprising? We may recall in this connection that if we restrict ourselves to Lie algebras of rank two, then the very existence of an octet with the same isospin and hypercharge contents as those of an SU(3) octet already implies that unitary symmetry is the only possible higher symmetry. This is because we know from our exhaustive study of Lie algebras of rank two[8] that no other symmetry groups can accommodate the octet structure. There is, however, no reason a priori to restrict ourselves to Lie algebras of rank two; some of the higher symmetry models considered in the past (e.g., Pais' doublet symmetry[9]) do have ranks higher than two. Nor can we exclude a priori the possibility of discrete symmetries (e.g., symmetry under $N \rightleftarrows \Xi$ contained in global symmetry) which lie outside Lie algebras. In fact, the mere appearance of an octet structure cannot be taken as evidence for unitary symmetry, as is evident from the example of global symmetry. On the other hand, our simple considerations do suggest that the appearance of mutually interacting octets (together with possible additional singlets, decuplets, etc.) can be taken as rather strong evidence for unitary symmetry.

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USE OF THE DEUTERON TO PROVIDE A POLARIZED PROTON TARGET

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We wish to show in this note that, with currently available techniques, one can use the deuteron to provide a polarized proton target for experiments in the BeV range. The deuteron consists of a neutron and a proton with their spins correlated in a triplet state. Suppose that in reactions such as $\pi^- + D \rightarrow n + \Lambda + K^0$ only the proton takes part, while the neutron stands by as a spectator. Then the nucleon spin correlation implies that a measurement of the polarization of the neutron gives information about the polarization of the proton. If we select an ensemble of events for which the spectator neutrons have polarization $\vec{\mathrm{P}}_S$, the effective proton polarization will be $\vec{\mathrm{P}}_T = \frac{1}{3}\vec{\mathrm{P}}_S$, corresponding to the fact that in the triplet state the spins are "parallel" two thirds of the time and "antiparallel" one third of the time. Hence proton polarizations up to a maximum of $\frac{1}{3}$ can be obtained. The main points we wish to make are that (A) there is evidence that the spectator particle assumption is already an excellent approximation at incident laboratory momenta above 1 BeV/c, and (B) it should be feasible to use scattering in He^4 to analyze the spectator neutron polarization.

(A) Theoretical criteria for the validity of the spectator assumption have been given by Chew and Wick[1] and by Chew and Goldberger.[2] As applied to deuterium target reactions, they are the following:

(1) The incident particle must not interact strongly with the neutron and the proton at the same time. The average interparticle spacing of the deuteron is large ($\bar{R} = 3.2$ F), giving only a 10% probability that a particle which is within 1.1 F of the proton is simultaneously within 1.1 F of the neutron.

(2) There must be little interference between direct production on the proton and production on the proton with subsequent final-state scattering on the neutron. For a reaction product with cross section σ for final-state scattering on the neutron and reduced wavelength $\lambda\!\!\!^{-}$, the quantitative criterion is $\chi = (\sigma/4\pi)^{1/2}\lambda\!\!\!^{-}\bar{R}^2 \ll 1$. For a typical reaction, $\pi^- + p \rightarrow K^0 + \Lambda$, at 1 BeV/$c$ incident π momentum, χ is less than $\frac{1}{25}$ for both the K and the Λ.

(3) The potential binding the deuteron must be much less than the energy of the incident particle, that is, $\phi = 25\ \mathrm{MeV}/E_{\mathrm{inc}} \ll 1$. For an in-