representation (the adjoint representation) of a simple Lie group.

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[6]The representation of SU(2) and SU(3) multiplicities 6 and 35, discussed recently by R. H. Capps [Phys. Rev. Letters 13, 536 (1964)], is a member of the SU(6) representation D^{700}. As seen from Eq. (3), the force in this representation is attractive, but weak.

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BARYON SUPERMULTIPLET

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In several recent papers[1-12] the remarkable correspondence between the 56-dimensional representation of SU(6) and the low-lying even-parity baryon states has been pointed out. Although the relations among these states have in the past[13-16] been described with some success in terms of a dynamical model which is based on dispersion relations and is an outgrowth of the Chew-Low model, the correspondence with SU(6) has been discussed in terms of unfamiliar dynamical concepts. We shall show here how the usual dynamical theory, with some minor extensions, can be interpreted as an SU(6) theory. Our model has the following features: (a) It is the natural approximation to a Lorentz-covariant theory pertaining to relatively heavy baryons. (b) The interactions of pseudoscalar mesons with the baryon octet and decuplet are taken to be the dominant interactions governing the structure of these states. (c) It incorporates a simple dynamical theory of the electromagnetic structure of the baryons.

We take the 35 SU(6) generators G_α to include the SU(3) generators as well as the total angular momentum in the baryon rest frame. In states containing a baryon and mesons we neglect the motion of the baryon; the total angular momentum is then decomposed into the spin of the central baryon and the angular momentum of the mesons with respect to this fixed baryon. Since pseudoscalar mesons are emitted by a baryon into P states, the pseudoscalar octet P provides a total of 24 mesonic states. To obtain the full complement of 35 states required by SU(6), we include provisionally an SU(3) singlet pseudoscalar meson X (which may be identified with the state at 960 MeV) and the states of the vector octet, V, which have $l=1$, $J=0$. We define coupling constants in such a way that the kinematical factors appear with the same coefficients in the vector and pseudoscalar states. These coupling constants are taken to be proportional to the generators $G_{ab\alpha}$.

The baryon-exchange force between a baryon and a meson is then proportional to

$$V_{a\alpha,b\beta}=G_{ac\beta}G_{cb\alpha}=G_{ac\alpha}G_{cb\beta}+F_{\alpha\beta\gamma}G_{ab\gamma}, \quad (1)$$

if we assume degeneracy, where the $F_{\alpha\beta\gamma}$ are the structure constants. In the representation N, this can be expressed in terms of the Casimir operators G^2 as

$$V(N)=G^2(N)\delta_{N,\underline{56}}+\tfrac{1}{2}[G^2(N)-G^2(\underline{56})-G^2(\underline{35})], \quad (2)$$

leading to[17] $V(\underline{56})=33/2$, $V(\underline{70})=-9$, $V(\underline{1134})=-1$, and $V(\underline{700})=+3$ (a positive sign denotes attraction). The strong attraction in $\underline{56}$ is consistent with a bootstrap picture. In contrast, the same calculation applied to the basic representation $\underline{6}$ gives $V(\underline{6})=-\frac{1}{6}$, $V(\underline{84})=-1$, and $V(\underline{120})=+1$, so no self-consistent model could be based on $\underline{6}$ alone.

To amplify this bootstrap discussion we may consider ladder-approximation equations in which the meson masses occur as parameters and the coupling constants and baryon masses are obtained by requiring self-consistency. The masses enter through integrals corresponding to triangle diagrams with appropriate internal form factors.[18] If in these integrals the average meson energies $\langle\omega_P\rangle$, $\langle\omega_X\rangle$, and $\langle\omega_V\rangle$ were equal, there would be a self-consistent solution with symmetrical coupling constants and degenerate baryon masses. The large masses of the X and of the octet V provide perturbations from SU(6) symmetry. However, the $\underline{56}$ supermultiplet is extremely stable against such perturbations; this is guaranteed by the fact that dynamical calculations which have omitted these particles also arrive at this supermultiplet and even at similar values for the ratio d/f for pseudoscalar mesons.

States with two orbital bosons are described by the symmetric part of $\underline{35}\otimes\underline{35}$. To allow for the effects of a strong boson-boson interaction we may include other boson resonances explicitly. The 35 states which can be identified with a component of $\underline{35}\otimes\underline{35}$ in the most natural way include the 24 states with $l=J=1$ of the vector octet, the S states of a hypothetical scalar octet S,[19] and either the S states of a singlet axial-vector meson (perhaps the 1410-MeV resonance), or the $l=J=1$ states of the singlet vector meson (ω). It is not necessary for our purposes that S consist of discrete or quasidiscrete states; an arbitrary continuum might suffice. Note also that the $J=0$ state of the ω is an SU(6) singlet.

It is not possible to make a rigid assignment of states to the two $\underline{35}$ supermultiplets without a detailed consideration of the actual three-boson vertices, which contribute to boson-exchange interactions. These interactions, which may have little resemblance to SU(6), could in some cases cause considerable mixing to take place. The mixing would determine the appropriate linear combinations of states that would make up the lowest-lying $\underline{35}$ and dominate in the baryon structure.

Bég, Lee, and Pais[7] and also Sakita[12] have noted that if the magnetic moment operator is assumed to transform like a component of $\underline{35}$, one obtains for the ratio $R=\mu_p/\mu_n$ the value $R=\frac{3}{2}$. (The experimental value is 1.457.) In our model this assignment arises from the bootstrap picture, in which the baryon is envisaged as a composite of a physical baryon and an orbiting boson. The magnetic moment in a state with $J_z=\frac{1}{2}$ is then made up of two terms: one term provided by the $J_z=\pm1$ charged bosons, and a second term contributed by the component baryon, for which we use the self-consistent value of the magnetic moment. The mesonic term obviously transforms in the same way as the generator J_zQ, and self-consistency thus requires that the baryon moment also does so.

To place this value of R in a better perspective, we give also the results of a calculation which does not use SU(6). If we use a theory with just nucleons and pions,[20] since the circulating pions give opposite currents in neutron and proton states, $R=1$. To include the kaon current,[21] we may use SU(3) and take into account only the baryon and pseudoscalar octets. In terms of the F/D mixing angle θ, one obtains[22]

$$R=\tfrac{1}{2}\sqrt{5}[\tfrac{7}{8}-(\cos^2\theta)/5+\tfrac{1}{8}\sin^2 2\theta]/\sin 2\theta. \quad (3)$$

As long as θ is in a reasonable range, R is insensitive to its value. We note two special cases: $R(32.9°)=1.54$, and $R(41.8°)=863/576=1.498$ [the first angle corresponds to the eigenstate of the decuplet-exchange potential; the second is the SU(6) value]. While these numbers show again that in our model the baryon states are very insensitive to SU(6)-breaking perturbations, they also show that the magnetic moments do not, any more than the masses in the baryon supermultiplet, test the special features of SU(6).

The main way in which this SU(6) model goes beyond previous dynamical calculations is that it ascribes a definite form to the couplings of vector mesons to baryons. The $J=0$ states correspond to "electric" coupling, which for the octet is predicted in our scheme to be "pure F," while the $J=1$ states correspond to "magnetic" coupling, for which $d/f=\frac{3}{2}$. This form implies a vanishing contribution to the neutron's electric form factor. A second difference is that whereas in previous dynamical calculations the $j=\frac{3}{2}$ 27-fold multiplet was found to have about half as strong an attraction as is responsible for the decuplet, Eq. (2) shows that this attraction is removed by the additional terms present in the SU(6) model. Accordingly, decuplet states may be more pure than previously supposed,[13,16,22] and perturbations from SU(3) symmetry may generally have less effect. For example, this might help to enhance the accuracy of the mass formula.

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MODEL OF WEAK INTERACTIONS WITH *CP* VIOLATION*

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We propose a simple model of weak interactions which allows for CP violation.[1] A single current-current coupling is introduced where vector and axial-vector currents transform differently under SU(3), yet each transforms like a member of a unitary octet.

We start from Cabibbo's elegant assumption[2] that the hadronic weak current—including both A_μ, the axial-vector current, and V_μ, the vector current—transforms under SU(3) like $\pi^+\cos\theta + K^+\sin\theta$. Then the weak current, like the electric current, transforms like a generator of SU(3). (Models with CP violation proposed by Sachs and Treiman[3] and by Sachs[4] invoke CP-odd currents with $I=\frac{3}{2}$. Such currents do not have octet transformation properties.) Furthermore, it is usually assumed that the weak currents are chosen from among a single octet of vector currents (the traceless 3×3 Hermitean matrix J_μ) and one of axial vector currents (the traceless 3×3 Hermitean matrix K_μ). These octets behave in a definite and identical fashion under CP, which may be taken to be $J_\mu(x,t)\to\tilde{J}_\mu(-x,t)$ and $K_\mu(x,t)\to\tilde{K}_\mu(-x,t)$, where tilde denotes matrix transposition. These are the 16 conserved currents of a chiral SU(3)⊗SU(3) symmetry which can hold in the limit of vanishing pseudoscalar meson masses.[5] (A model with CP violation due to Cabibbo[6] requires the introduction of other octets of currents with opposite CP properties. Matrix elements of these abnormal currents are "of the second kind"[7] and give rise to observable CP violations.)

We modify the original Cabibbo proposal by introducing neither non-octet currents nor abnormal octet currents. Rather, we let V_μ and A_μ transform like different members of a unitary octet.[8] We assume that V_μ transforms like $\pi^+\cos\theta_V + K^+\sin\theta_V$, and that A_μ transforms like $\pi^+e^{i\Phi'}\cos\theta_A + K^+e^{i\Phi}\sin\theta_A$. We lose no generality writing V_μ as a real linear combination of π^+ and K^+, since the overall phase of the weak current and the relative phase of its $Y=0$ and $Y=1$ parts are unobservable. Because nuclear β decay seems CP invariant, we put $\Phi'=0$; because of the success of Cabibbo's model in relating decay rates,[9] we put $\theta_V=\theta_A=\theta$. We are left with a two-parameter description of the weak current involving $\theta\approx15°$ (the relative strength of the $Y=0$ and $Y=1$ currents) and Φ (the degree of CP violation, which may or may not be small):

$$V_\mu = \mathrm{Tr}J_\mu C = \mathrm{Tr}J_\mu \begin{bmatrix} 0 & \cos\theta & \sin\theta \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}, \tag{1}$$