Comments and Addenda

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SU(3) context of a new weak current

Richard Pappas and Marcel Wellner
Physics Department, Syracuse University, Syracuse, New York 13210
(Received 30 June 1975)

A recently proposed weak isosinglet current is shown to bear a close relation to the group SU(3).

On the basis of self-consistency arguments we recently proposed[1] that a new isoscalar weak or superweak current $\mathfrak{X}$ should exist, to which the spin-$\frac{1}{2}$ baryons contribute the terms

$$\mathfrak{X} = \alpha(N^\dagger N + \Xi^\dagger \Xi) + \beta\Lambda^*\Lambda \tag{1}$$

for some parameters α and β. In the expression above the spin variables are suppressed for brevity, but it was shown that $\mathfrak{X}$ must be of the chiral form $V+A$ (the usual one being $V-A$). The ratio β/α was determined from the experimental masses of the baryons:

$$\beta/\alpha = 2.007 \pm 0.005 . \tag{2}$$

One deficiency in this proposal was the apparent lack of connection between $\mathfrak{X}$ and the generators of any familiar symmetries. It is the purpose of this note to supply such a connection, namely with SU(3), and to draw some conclusions therefrom.

We consider the baryonic SU(3) algebra in the octet $V+A$ representation (spin dependence will be suppressed throughout the discussion):

$$J_\alpha^f = i \sum_{\beta,\gamma=1}^{8} f_{\alpha\beta\gamma}\psi_\beta^*\psi_\gamma \quad (\alpha = 1, \ldots, 8). \tag{3}$$

We next enlarge this algebra by forming another octet of $V+A$ currents[2]

$$J_\alpha^d = \sum_{\beta,\gamma=1}^{8} d_{\alpha\beta\gamma}\psi_\beta^*\psi_\gamma + (\tfrac{2}{3})^{1/2}(\psi_0^*\psi_\alpha + \psi_\alpha^*\psi_0) \quad (\alpha = 1, \ldots, 8). \tag{4}$$

The subscript zero designates a ninth baryon which is an SU(3) scalar. The 16 currents J^f and J^d together form an algebra; taking sums and differences, one obtains $SU(3)_{f+d} \times SU(3)_{f-d}$.

We now restrict our attention to the J_α^d with $\alpha = 1$, 2, 3, and 8, i.e., to the isovector and isoscalar currents. In terms of the baryonic hypercharge states, we have

$$J_\alpha^d = \tfrac{1}{2}(N^\dagger\tau_\alpha N - \Xi^\dagger\tau_\alpha\Xi) + (1/\sqrt{3})(\psi_8^*\Sigma_\alpha + \Sigma_\alpha^*\psi_8) + (\tfrac{2}{3})^{1/2}(\psi_0^*\Sigma_\alpha + \Sigma_\alpha^*\psi_0) \quad (\alpha = 1, 2, 3), \tag{5}$$

$$J_8^d = -\frac{1}{2\sqrt{3}}(N^\dagger N + \Xi^\dagger\Xi) + \frac{1}{\sqrt{3}}\vec{\Sigma}^*\cdot\vec{\Sigma} - \frac{1}{\sqrt{3}}\psi_8^*\psi_8 + (\tfrac{2}{3})^{1/2}(\psi_0^*\psi_8 + \psi_8^*\psi_0). \tag{6}$$

The dependence of ψ_0 and ψ_8 on the physical wave functions of the Λ and of the hypothetical ninth baryon L is in general as follows:

$$\psi_8 = e^{i\mu}\Lambda\cos\sigma + e^{i\nu}L\sin\sigma ,$$
$$\psi_0 = e^{i(\nu+\rho)}L\cos\sigma - e^{i(\mu+\rho)}\Lambda\sin\sigma , \tag{7}$$

for arbitrary angles μ, ν, ρ, and σ.

Next we compare the J_α^d $(\alpha = 1,2,3)$ with the D-type currents that were used in compensation theory[3],

$$\mathcal{J}_\alpha \propto \tfrac{1}{2}(N^\dagger\tau_\alpha N - \Xi^\dagger\tau_\alpha\Xi) + i(\Sigma_\alpha^* L - L^*\Sigma_\alpha) \quad (\alpha = 1, 2, 3), \tag{8}$$

and attempt the identification

$$\mathcal{J}_\alpha = J_\alpha^d \quad (\alpha = 1, 2, 3). \tag{9}$$

This implies

$$iL = (1/\sqrt{3})(\psi_8 + \sqrt{2}\,\psi_0). \tag{10}$$

We construct the most general wave function orthogonal to this,

$$i\Lambda=(1/\sqrt{3})e^{i\varphi}(\psi_0-\sqrt{2}\,\psi_8)\,, \tag{11}$$

for some angle φ. Hence

$$\psi_8=(i/\sqrt{3})(L-\sqrt{2}\,e^{-i\varphi}\Lambda)\,,$$
$$\psi_0=(i/\sqrt{3})(\sqrt{2}\,L+e^{-i\varphi}\Lambda)\,. \tag{12}$$

Insertion in (6) gives

$$J_8^d=(1/\sqrt{3})[-\tfrac{1}{2}(N^\dagger N+\Xi^\dagger\Xi)+\vec{\Sigma}^*\cdot\vec{\Sigma}+L^*L-2\Lambda^*\Lambda]\,. \tag{13}$$

If we now define the SU(3)-scalar $V+A$ current

$$J_0=\sum_{\alpha=0}^{8}\psi_\alpha^*\psi_\alpha$$
$$=N^\dagger N+\Xi^\dagger\Xi+\vec{\Sigma}^*\cdot\vec{\Sigma}+\Lambda^*\Lambda+L^*L\,, \tag{14}$$

which commutes with all the other currents, then $\mathfrak{X}$ is uniquely obtained (up to a normalization) by the linear combination

$$\mathfrak{X}\propto J_0-\sqrt{3}J_8^d\,, \tag{15}$$

provided we take, in Eq. (1), $\beta/\alpha=2$. Thus *the exact ratio* $\beta/\alpha=2$ *is the only one compatible with the SU(3)×SU(3) V+A algebra.*

Aside from building a more solid foundation for the existence of $\mathfrak{X}$, such a result leads to the following observations.

(a) Equation (2) appears to provide one of the most accurate verifications of SU(3) (as a weak-interaction algebra) so far.

(b) Our result is a second independent piece of evidence for the existence of the baryon-number current J_0 (or $\mathfrak{B}$) in the $V+A$ form. (The earlier evidence[4] stemmed from the electromagnetic mass difference of the baryons.)

(c) One term of $\mathfrak{X}$, namely J_8^d, belongs to an algebra of currents which are known, in the context of our model, to have mesonic contributions. Hence $\mathfrak{X}$ itself should have mesonic contributions, a fact not previously evident.

(d) The circumstance that J_8^d belongs to SU(3) ×SU(3), rather than being a mere singlet, raises the likelihood that the strange currents of that $V+A$ algebra also play a role in the theory. Future work ought to elucidate how such a role is compatible with the absence of strange $V+A$ currents in earlier, self-consistent calculations.[5]

(e) The nontrivial self-consistency feature which, in Ref. 1, helps motivate the form of $\mathfrak{X}$, is not yet explained by its relation to SU(3), since symmetry considerations are not applicable. The speculative conclusion of a spontaneously broken symmetry remains as attractive as ever.

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[1]R. Pappas and M. Wellner, Phys. Rev. D 11, 318 (1975).

[2]The commutation properties of the D-type currents were used by M. Gell-Mann, Physics (N.Y.) 1, 63 (1964); see also S. Adler and R. Dashen, *Current Algebras and Applications to Particle Physics* (Benjamin, New York, 1968), p. 26.

[3]M. Wellner, Ann. Phys. (N.Y.) 73, 180 (1971), see especially Appendix D.

[4]M. Wellner, Phys. Rev. D 9, 2471 (1974).

[5]See Ref. 3, as well as R. Pappas, Ph.D. dissertation, Syracuse University, 1975 (unpublished).