SCALAR MESONS AND THE BREAKING OF SU(3)

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An argument is given to support the theorem that the divergences of the strangeness-changing vector currents, if considered to the first order of magnitude in the medium strong interactions, are proportional to scalar fields belonging to 8_D of $SU(3)$.

Several years ago Nambu and Sakurai [1] expressed the important idea that some scalar strange mesons are responsible for breaking the SU(3) symmetry. The mechanism proposed by these authors was the partial conservation of the strangeness-changing vector currents, whereas the conservation of the strangeness-nonchanging vector currents was provided by the absence of any scalar mesons different from those with $I = 1/2$ (and $Y = \pm 1$). While the experimental status of scalar mesons remains still unclear, the Nambu-Sakurai idea seems to be important enough to reformulate it in such a way that only $I = 1/2$ (and $Y = \pm 1$) scalar mesons could spoil the SU(3) symmetry (besides the electromagnetic breaking), even if other scalar mesons existed [2]. Along this line we conjecture in this note the following theorem: *the divergences of the strangeness-changing vector currents are equal to linear combinations of some scalar fields belonging to strange isodoublets within SU(3) multiplets* $\boldsymbol{8_D}$ *and* $\boldsymbol{27}$, *where the coefficients are of the first and second order, respectively, in the medium strong interactions.* Of course, the mentioned property of the coefficients is consistent with the Ademollo-Gatto theorem [3], since here the renormalization of the vector currents appears, as it should, in the second order in the medium strong interactions. As a matter of fact, the contributions to the renormalization from $\boldsymbol{8_D}$ are of the second order, whereas the mixed contributions from $\boldsymbol{8_D}$ and $\boldsymbol{27}$ are of the third order, and the contributions from $\boldsymbol{27}$ are of the fourth order.

In the present note we intend to give an argument supporting our theorem. To do this we consider two broken SU(3) octets of the renormalized fields $\psi^\alpha(x)$ and $\varphi^\alpha(x)$ describing baryons with physical masses M_α and pseudoscalar mesons with physical masses m_α, respectively. Then the vector currents are:

$$V_\mu^\alpha(x) = f^{\alpha\beta\gamma}\,\{\bar{\psi}^\beta(x)\gamma_\mu\psi^\gamma(x) + \tfrac{1}{2}\,[\partial_\mu\varphi^{+\beta}(x)\,\varphi^\gamma(x) - \varphi^{+\beta}(x)\,\partial_\mu\varphi^\gamma(x)]\}. \tag{1}$$

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Assuming that the SU(3) symmetry is broken only by the mass terms in the renormalized lagrangian, we obtain from (1):

$$\partial_\mu V^\alpha_\mu(x) = f^{\alpha\beta\gamma}[(M_\beta - M_\gamma)\,\bar{\psi}^\beta(x)\psi^\gamma(x) + \tfrac{1}{2}(m^2_\beta - m^2_\gamma)\varphi^{+\beta}(x)\,\varphi^\gamma(x)]. \tag{2}$$

Now, we reduce the products $\bar{\psi}^\beta(x)\,\psi^\gamma(x)$ and $\varphi^{+\beta}(x)\,\varphi^\gamma(x)$ according to the formula $\boldsymbol{8}\times\boldsymbol{8} = \boldsymbol{1}+\boldsymbol{8}_F+\boldsymbol{8}_D+\boldsymbol{10}+\boldsymbol{10}^*+\boldsymbol{27}$. To do this we write

$$\bar{\psi}^\beta(x)\,\psi^\gamma(x) = \sum_n \begin{pmatrix} 8 & 8 & n \\ \beta & \gamma & A_n \end{pmatrix} S^{A_n}_{n\psi}(x) \tag{3}$$

and

$$\varphi^{+\beta}(x)\,\varphi^\gamma(x) = \sum_n \begin{pmatrix} 8 & 8 & n \\ \beta & \gamma & A_n \end{pmatrix} S^{A_n}_{n\varphi}(x), \tag{4}$$

where $\begin{pmatrix} 8\, 8\, n \\ \beta\, \gamma\, A_n \end{pmatrix}$ are Clebsch–Gordan coefficients of $SU(3)$, [4] and $S^{A_n}_{n\psi}(x)$ and $S^{A_n}_{n\psi}(x)$ are scalar fields being projections of the products onto representation subspaces $n = 1, 8_F, 8_D$, 10, 10* and 27. Inserting (3) and (4) into (2) we get

$$\partial_\mu V^\alpha_\mu(x) = f^{\alpha\beta\gamma}\left\{\begin{pmatrix} 8 & 8 & 8_D \\ \beta & \gamma & A_{8_D} \end{pmatrix}\left[(M_\beta - M_\gamma)\,S^{A_{8_D}}_{8_D\psi}(x) + \frac{1}{2}\,(m^2_\beta - m^2_\gamma)\,S^{A_{8_D}}_{8_D\varphi}(x)\right] + \right.$$
$$\left. + \begin{pmatrix} 8 & 8 & 27 \\ \beta & \gamma & A_{27} \end{pmatrix}\left[(M_\beta - M_\gamma)\,S^{A_{27}}_{27\psi}(x) + \frac{1}{2}\,(m^2_\beta - m^2_\gamma)\,S^{A_{27}}_{27\varphi}(x)\right]\right\}. \tag{5}$$

If we neglect the electromagnetic mass splitting we obtain from (5):

$$\partial_\mu[V^1_\mu(x) + iV^2_\mu(x)] = 0,$$
$$\partial_\mu V^3_\mu(x) = 0,$$
$$\partial_\mu[V^4_\mu(x) + iV^5_\mu(x)] = -i[\varepsilon_{8_D\psi}S^-_{8_D\psi}(x) + \varepsilon_{8_D\varphi}S^-_{8_D\varphi}(x)] -$$
$$-i[\varepsilon_{27\psi}S^-_{27\psi}(x) + \varepsilon_{27\Phi}S^-_{27\varphi}(x)],$$
$$\partial_\mu[V^6_\mu(x) + iV^7_\mu(x)] = -i[\varepsilon_{8_D\psi}S^0_{8_D\psi}(x) + \varepsilon_{8_D\varphi}S^0_{8_D\varphi}(x)] -$$
$$-i[\varepsilon_{27\psi}S^0_{27\psi}(x) + \varepsilon_{27\varphi}S^0_{27\varphi}(x)],$$
$$\partial_\mu V^8_\mu(x) = 0, \tag{6}$$

where

$$\varepsilon_{8_D\psi} = \sqrt{\frac{6}{5}}\left(\frac{M_N + M_\Xi}{2} + \frac{M_\Lambda - 3M_\Sigma}{2}\right),$$
$$\varepsilon_{27\psi} = 2\sqrt{\frac{6}{5}}\left(\frac{M_N + M_\Xi}{2} - \frac{3M_\Lambda + M_\Sigma}{4}\right),$$
$$\varepsilon_{8_D\varphi} = \sqrt{\frac{6}{5}}\left(m^2_K + \frac{m^2_8 - 3m^2_\pi}{2}\right),$$
$$\varepsilon_{27\varphi} = 2\sqrt{\frac{6}{5}}\left(m^2_K - \frac{3m^2_8 + m^2_\pi}{4}\right). \tag{7}$$

Here $S^0_{n\psi}(x)$ and $S^-_{n\psi}(x)$ as well as $S^0_{n\varphi}(x)$ and $S^-_{n\varphi}(x)$ ($n = 8_D$ and 27) are scalar fields (some of the previous S's) forming strange isodoublets within SU(3) multiplets $\mathbf{8}_D$ and **27** ($S^0_{n\psi}$ and $-S^0_{n\psi}$ as well as $S^0_{n\varphi}$ and $-S^-_{n\varphi}$ form isospinors of the second kind). As we can see from (7) the constants $\varepsilon_{8_D\psi}$ and $\varepsilon_{8_D\varphi}$ are of the first order, and $\varepsilon_{27\psi}$ and $\varepsilon_{27\varphi}$ of the second order in the medium strong interactions, respectively. So, we conclude that our theorem is true in the considered model of strong interactions.

It is likely that if we assume dominance of the divergences $\partial_\mu V^\alpha_\mu(x)$ by scalar mesons, we get the relations (compare (2))

$$\partial_\mu V^\alpha_\mu(x) = af^{\alpha\beta\gamma}\frac{1}{2}(m^2_\beta - m^2_\gamma)\varphi^{\beta\gamma}(x), \tag{8}$$

where a is a constant and $\varphi^{\beta\gamma}(x)$ are scalar meson fields forming a symmetric 8×8 $SU(3)$ tensor. Then reducing the tensor $\varphi^{\beta\gamma}(x)$ and neglecting the electromagnetic mass splitting we obtain from (8):

$$\begin{aligned} \partial_\mu[V^1_\mu(x)+iV^2_\mu(x)] &= 0,\\ \partial_\mu V^3_\mu(x) &= 0,\\ \partial_\mu[V^4_\mu(x)+iV^5_\mu(x)] &= -ia[\varepsilon_{8_D\varphi}\varphi^-_{8_D}(x)+\varepsilon_{27\varphi}\varphi^-_{27}(x)],\\ \partial_\mu(V^6_\mu(x)+iV^7(x)] &= -ia[\varepsilon_{8_D\varphi}\varphi^0_{8_D}(x)+\varepsilon_{27\varphi}\varphi^0_{27}(x)],\\ \partial_\mu V^8_\mu(x) &= 0, \end{aligned} \tag{9}$$

where $\varphi^0_n(x)$ and $\varphi^-_n(x)$ ($n = \mathbf{8}_D$ and **27**) describe strange isodoublets of scalar mesons belonging to $\mathbf{8}_D$ and **27**. Eqs (9) are dynamical relations expressing partial conservation of vector currents (PCVC). If the medium strong interactions are neglected, then obviously PCVC goes over into a true conservation (CVC).

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