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The three-triplet quark model of Bogolubov, Struminsky and Tavkhelidze [1] and Han and Nambu [2] is suggestive on the new hadron symmetries and the new particle pattern. It is natural, therefore, to attempt an interpretation of ψ-mesons [3,4] as a manifestation of the new hadronic degree of freedom offered by the model. Earlier [5] we have proposed to interpret the ψ's within $SU(3) \times S_3$ symmetry studied by one of the authors [6]. The aim of this note is to demonstrate that the same result can be obtained in the $SU(3) \times SU(3)^c$ symmetry [2] ("c" = color) and to discuss in more detail the predictions concerning the decays of new particles.

The basic assumptions we adopt are as follows:

1) The hadrons are classified according to the $SU(3) \times SU(3)^c$ symmetry.
2) Masses of the particles related to higher $SU(3)^c$ - representations differ substantially ($\Delta m \gtrsim 2$ GeV) from those of "usual" hadrons assumed to be $SU(3)^c$ - singlets.
3) The $SU(3)^c$ is broken by the electromagnetic interactions. In particular, the electromagnetic interactions are responsible for decays of new hadrons into "color"-singlet ones.

4) The electromagnetic current has the following structure

$$J_\mu^{e.m.} = J_\mu\,(8,1^c) + J_\mu\,(1,8^c)$$

$$= \bar{t}_{p2}\,\gamma_\mu t_{p2} + \bar{t}_{p3}\,\gamma_\mu t_{p3} - \bar{t}_{n1}\,\gamma_\mu t_{n1} - \bar{t}_{\lambda 1}\,\gamma_\mu t_{\lambda 1}\,, \qquad (1)$$

where $t_{\alpha i}$ ($\alpha = p,n,\lambda$; $i = 1,2,3$) stands for the fundamental quark nonet.

5) The mesons are the $t\bar{t}$ - bound states and transform according to

$$t \otimes \bar{t} = (3,\bar{3}^c) \otimes (\bar{3},3^c) = (1 \oplus 8,1^c) + (1 \oplus 8,8^c). \qquad (2)$$

Together with the quantum numbers I, I_3 and Y of the usual SU(3) the meson multiplets are labelled by I^c, I_3^c and Y^c of the $SU(3)^c$.

Consider now the hyperneutral vector mesons with $I_3 = Y =$ $= I_3^c = Y^c = 0$. Our main dynamical assumption is the degeneracy of the mesons with $I^c = 1$ and $I^c = 0$ when the electromagnetic interactions are absent. "Switching-on" the electromagnetism results in the "physical" state vectors in the form of superposition

$$\tilde{V}^o = \frac{\sqrt{3}}{2}|I^c=1;8^c\rangle + \frac{1}{2}|I^c=0;8^c\rangle = \frac{1}{\sqrt{6}}(2t_1\bar{t}_1 - t_2\bar{t}_2 - t_3\bar{t}_3), \qquad (3)$$

$$\approx\!\!\!\!V^o = -\frac{1}{2}|I^c=1;8^c\rangle + \frac{\sqrt{3}}{2}|I^c=0;8^c\rangle = \frac{1}{\sqrt{2}}(t_2\bar{t}_2 - t_3\bar{t}_3)\,. \qquad (4)$$

Accepting the SU(3) breaking to be due to relative increasing of mass of the λ-quark (but this increase is not necessary the same in different $SU(3)^c$ - representations!) we have the usual vector nonet structure with near "ideal" singlet-octet mixing.

Hence, the existence is predicted of 3 "doublets" of new hyperneutral vector mesons: $(\tilde{\rho}^o, \approx\!\!\rho^o), (\tilde{\omega}^o, \approx\!\!\omega^o)$ and $(\tilde{\varphi}^o, \approx\!\!\varphi^o)$. The mass splitting of the doublet members should be of the order of a few MeV (i.e., of the order of the meson mass splitting in the isospin multiplets).

It is of primary importance that by virtue of Eqs.(1),(3) and (4) only two new mesons, $\tilde{\omega}$ and $\tilde{\varphi}$, are produced in the e^+e^- - annihilation considered in the one-photon approximation. We identify them with the observed ψ's: $\psi_1(3105) \equiv \tilde{\omega}$, $\psi_2(3695) \equiv \tilde{\varphi}$. In the "ideal" $\tilde{\omega} - \tilde{\varphi}$ mixing approximation, when $\tilde{\varphi}$ consists of the λ-quark only one obtains the following relation of the leptonic decay widths /5/

$$\Gamma(\omega \equiv \psi_1(3105) \to e^+e^-) : \Gamma(\varphi \equiv \psi_2(3695) \to e^+e^-) = 2:1. \quad (5)$$

The data analysis /7,8/ gives for this ratio *)

$$(5.3 \pm 0.2 \text{ keV}):(3.3 \pm 0.5 \text{ keV}) = 1.6 \pm 0.25\,.$$

*) If the ratio $g_{\tilde{\omega}}^{-2} : g_{\tilde{\varphi}}^{-2} = 2:1$ is adopted for dimensionless constants of the "photon-vector meson" transition then, instead of (5), for the ratio of leptonic widths we have the following value $2m(\psi_1)/m(\psi_2) = 1{,}67$. It is also of interest to notice that the ratios $g_\rho^{-2}:g_\omega^{-2}:g_\varphi^{-2}:g_{\tilde{\omega}}^{-2}:g_{\tilde{\varphi}}^{-2} = 9:1:2:8:4$ including both constants g_V and $g_{\tilde{V}}$ are strongly violated. If, however, these ratios are rewritten in terms of widths themselves we obtain unexpected good agreement with experiment

$$\frac{1}{9}\Gamma(\rho \to e^+e^-):\Gamma(\omega \to e^+e^-):\frac{1}{2}\Gamma(\varphi \to e^+e^-):\frac{1}{8}\Gamma(\tilde{\omega} \to e^+e^-):\frac{1}{4}\Gamma(\tilde{\varphi} \to e^+e^-)$$

$=(0.72 \pm 0.10):(0.76 \pm 0.08):(0.67 \pm 0.07):(0.66 \pm 0.07):(0.82 \pm 0.12)$ ($[\Gamma]$ = keV). In the framework of the SU(4)-model with the "charmed" quark these ratios have been noted by Yennie /7/, of course, with exception for $\psi_2(3695)$ prediction for which is a peculiarity of the model under consideration.

The isospin selection rules follow from unitary structure of the electromagnetic current

$$\tilde{\rho} \to \gamma + X("1^c", I^G = 1^-);\ X = \pi, A_1, A_2, \ldots \qquad (6)$$

$$\tilde{\omega}, \tilde{\varphi} \to \gamma + X("1^c", I^G = 0^+);\ X = \eta, \eta', \ldots \qquad (7)$$

The critical point for the model is the necessity of explaining very small width of $\psi_1(3105)$:

$$\Gamma(\psi_1 \to \text{hadrons} + \gamma) \leq 80 - 100 \text{ keV}.$$

Qualitatively we relate this phenomenon with the very large mass difference of particles involved (e.g., in the channel $\tilde{\omega} \equiv \psi_1(3105) \to \gamma + \eta(550)$). The "effetive" mass of quarks composing the new (ψ) and the "usual" (for instance, η) mesons may be considered to be quite different (for the λ-quark it is seen from inequality $m_{\tilde{\varphi}} - m_{\tilde{\omega}} > m_{\varphi} - m_{\omega}$). This fact, in turn, may result in a strong suppression of the Dirac transition current, hence, in the suppression of the **radiative widths** of $\tilde{\omega} \to \gamma + \eta, \eta'$, etc. (the Pauli current of quarks is commonly accepted insignificant). However, the virtual photon transitions, like $\tilde{\omega} \to \eta + \gamma^* \to \eta + \rho \to 5\pi$, may proceed with significant probability.

We turn now to the strong decays of the $\psi_2(3695)$. The following transitions

$$\psi_2(\equiv \tilde{\varphi}) \to \psi_1(\equiv \tilde{\omega}) + 2\pi, \qquad (8)$$

$$\psi_2(\equiv \tilde{\varphi}) \to \tilde{\rho}^{\pm,0} + \pi^{\mp,0} \qquad (9)$$

are possible. Relying on the Okubo-Iizuka-Zweig rule /9/ we consider the decay modes (8) and (9) to **be due to small admixture of**

the nonstrange quarks to the state vector of ψ_2, i.e., due to the deviation $\delta = \theta - \theta_0 \neq 0$ of the singlet-octet mixing angle θ from its "ideal" value $\theta_0 \cong 35^0$ ($tg\,\theta_0 = \frac{1}{\sqrt{2}}$). As a dynamical reason for $\theta \neq \theta_0$ we assume some effective potential $\hat{V}(\Delta S \neq 0)$ with dimension either of "mass^2" or of "mass", which yields the quark hypercharge exchange: $\lambda\bar{\lambda} \to p\bar{p}(n\bar{n})$. Taking $\varphi_0 = -\lambda\bar{\lambda}$ and $\omega_0 = \frac{1}{\sqrt{2}}(p\bar{p} + n\bar{n})$ as a zero-range wave function we obtain the correction in the first order of perturbation theory (hereafter we use the "mass^2" – prescription)

$$\omega \cong \omega_0 + \sin\delta \cdot \varphi_0,$$

$$\varphi \cong \varphi_0 - \sin\delta \cdot \omega_0,$$

$$\sin\delta = \frac{\langle \omega_0 | \hat{V}_{\Delta S} | \varphi_0 \rangle}{m^2_{\omega_0} - m^2_{\varphi_0}} \approx \frac{\langle \omega_0 | \hat{V}_{\Delta S} | \varphi_0 \rangle}{m^2_{\omega} - m^2_{\varphi}}. \qquad (10)$$

Putting approximately $\langle \omega_0 | \hat{V}_{\Delta S} | \varphi_0 \rangle = \langle \tilde{\omega}_0 | \hat{V}_{\Delta S} | \tilde{\varphi}_0 \rangle$, we get

$$\frac{\sin\tilde{\delta}}{\sin\delta} = \frac{m^2_{\varphi} - m^2_{\omega}}{m^2_{\tilde{\varphi}} - m^2_{\tilde{\omega}}} = 0.1 \qquad (11)$$

Assuming further $g_{\tilde{\rho}\tilde{\omega}\pi} = g_{\rho\omega\pi}$ one obtains

$$\Gamma(\psi_2 \equiv \tilde{\varphi} \to \tilde{\rho} + \pi) = \Gamma(\varphi \to 3\pi) \frac{\sin^2\tilde{\delta}}{\sin^2\delta} \left(\frac{k_{\tilde{\varphi}\tilde{\rho}\pi}}{k_{\varphi\rho\pi}}\right)^3 \cong 0.2 \text{ MeV}, (12)$$

where k is the pion momentum in the c.m.s. of an appropriate channel and we believe $\varphi \to 3\pi$ goes via $\varphi \to \rho\pi \to 3\pi$.

The estimate obtained is in accord, by the order of magnitude, with data [4]. (Note that using the linear mass relations in Eqs.(10) and (11) would give the result as large as 2.5 MeV in Eq.(12), which appears to be also within the experimental limits for $\Gamma_{tot}(\psi_2)$).

To estimate the branching ratio of the three-particle mode (8) we assume the decay goes via appearance of the σ-meson ($J^P = 0^+, I^G = 0^+$) in the intermediate state: $\tilde{\varphi} \to \tilde{\omega} + \sigma \to \tilde{\omega} + 2\pi$. We consider the vector fields in the effective Lagrangians to be taken in the form of the proper contraction of the strength tensors. Accepting roughly $g_{\tilde{\omega}\tilde{\omega}\sigma} = g_{\tilde{\omega}\tilde{\rho}\pi}$ and making use of the Breit-Wigner mass distribution for the σ with the parameters $m_\sigma = 700$ MeV and $\Gamma_\sigma = 400$ MeV one gets

$$\frac{\Gamma(\psi_2(\equiv\tilde{\varphi}) \to \psi_1(\equiv\tilde{\omega}) + \pi^+ + \pi^-)}{\Gamma(\psi_2(\equiv\tilde{\varphi}) \to \tilde{\rho} + \pi)} \cong 0.3 \qquad (13)$$

in qualitative agreement with experiment.

Whatever the numerical values might be we should stress that the main consequence of our model is that the two-particle mode (9) with the $\tilde{\rho}^{\pm,0}$ - emission ($m_{\tilde{\rho}} \cong m_{\tilde{\omega}} = 3.1$ GeV) should be dominant decay mode of $\psi_2(3695)$. The $\tilde{\rho}$'s from the decay $\psi_2 \to \tilde{\rho}^{\pm} + \pi^{\mp}$ could be observed by search for maximum at ~ 530 MeV/c in the charged pion one-particle distribution spectrum. (It is of relevance to point out here an independent evidence[10] for the meson resonance $X^-(3145)$ with $\Gamma_{tot} < 10$ MeV).

Application of the Okubo-Iizuka-Zweig rule and our results(5) and (11) leads to a large suppression factor of order

$\frac{1}{2}\sin^2\tilde{\delta} = 10^{-3} - 10^{-4}$ for the cross-section of $pp \to \psi_2 + \ldots \to e^+e^- + \ldots$ in comparison with the reaction $pp \to \psi_1 + \ldots \to e^+e^- + \ldots$, in agreement with experiments on the (non-associative) ψ -production in p - Be collisions [11].

Concluding remark will refer to the broad $\psi_3(4150)$-resonance with the leptonic width $\Gamma(\psi_3(4150) \to e^+e^-) \cong 4$ keV discovered quite recently in e^+e^- - annihilation.[12] It is naturally to suppose the $\psi_3(4150) \equiv \tilde{\omega}'$ being a radial excitation of the $\tilde{\omega} \equiv \psi_1(3105)$. Then the main decay modes will be as follows:

$$\psi_3(4150) \begin{cases} \nearrow \tilde{\omega}(3105) + 2\pi \\ \searrow \tilde{\rho} + \pi \end{cases} \qquad (14)$$

and the multi-pion configurations should mainly be observed in the final states. The symmetry arguments require the existence of an analogous excited state of the $\tilde{\varphi} \equiv \psi_2(3695)$ with a mass in the region 4.6 - 4.8 GeV and with the leptonic width equal to one-half that of $\psi_3(4150)$. This resonance being composed of λ-quarks will decay predominantly into channels where the K-mesons should be present.

Finally we would like to state the principal difference between two new "colored" symmetries, $SU(3)^c$ and S_3^c [5], with respect to other vacant states. The $SU(3)^c$ admits of the existence of the long-lived weakly decaying "colored" particles (with $I_3^c \neq 0$ and $Y^c \neq 0$) and even the quarks may appear in the free states[2], while the S_3^c rules out such particles [6].

As this note was in preparation, our attention was drawn to the preprint by M.Krammer et al.[13] who used the approach analogous to ours. The substantional difference between two approaches is that contrary to [13] we do not assume the coupling constants in the vector-vector-pseudoscalar vertices to be very different for the new and "usual" vector mesons (see derivation of Eq.(12)). To suppress the radiative decays (7) M.Krammer et al. [13] made the assumption $g_{\tilde{V}\tilde{V}P} \ll g_{VVP}$. Other possible mechanism for the required suppression without using this condition was mentioned in the text.

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