Masses of charmed mesons and $SU(8)$ symmetry

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(Submitted July 29, 1975)
Pis'ma Zh. Eksp. Teor. Fiz. **22**, No. 6, 351–353 (20 September 1975)

The group $SU(8)$, which combines $SU(4)$ and $SU(2)$ spin, is considered as an expanded hadron symmetry group. The possible masses of the D, F, D^*, and F^* mesons are calculated on the basis of the derived mass relations.

PACS numbers: 12.70., 14.40., 11.30.L, 12.40.D

The discovery of the vector particles $\Psi(3105)$ and $\Psi'(3695)$ [1] has intensified the search for symmetries higher than $SU(3)$. The most widely used is the $SU(4)$ scheme, in which the Ψ meson is regarded as a bound state of a charmed quark and a charmed antiquark.[2,3]

When account is taken of the quark spin, if we assume unitary $SU(4)$ and spin independence of the superstrong interactions in analogy with Wigner's $SU(4)$ nuclear model and the $SU(6)$ model of elementary particles, then we obtain the $SU(8)$ group as the hadron symmetry group.

This article considers certain consequences of $SU(8)$ symmetry for mesons. Mass relations are obtained for the terms of the regular representation of $SU(8)$, accurate to the $SU(3)$ unitary splitting. These relations are used to find the masses of the charmed mesons with $J^{PC} = 0^{-+}$ and 1^{--}.

An important role should be played in $SU(8)$ theory by two reductions [(1) and (2)] of $SU(8)$ into subgroups, namely:

Reduction (1), in which the spin-connected transformations are explicitly separated

$$SU(8) \supset SU(2) \times SU(4). \tag{1}$$

Reduction (2), in which the transformations connected with the new quantum number (charm) are explicitly separated

$$SU(8) \supset U_C(1) \times SU_C(2) \times SU(6), \tag{2}$$

where $U_C(1)$ is the gauge group connected with the charm, and $SU_C(2)$ is a group connected with the spin of the charmed quarks.

The reductions (1) and (2) lead to the following expansions for the regular representation of $SU(8)$ of dimensionality 63:

$$\begin{aligned} [63] &= (1,15) + (3,15) + (3,1), \\ [63] &= (0,1,1) + (0,3,1) + (0,1,35) + (1,2,6) + (-1,2,\bar{6}), \end{aligned} \tag{3}$$

where k_1 and k_2 in (3) denote the dimensionalities of the (k_1, k_2) multiplet with respect to the $SU(2)$ and $SU(4)$ group, respectively, and k_0 in (4) is the value of the charm, while k_1 and k_2 are the dimensionalities of the (k_0, k_1, k_2) multiplet with respect to $SU_C(2)$ and the $SU(6)$ groups, respectively.

Continuing the reduction (2) in the following manner:

$$SU(8) \supset U_C(1) \times SU_C(2) \times U_S(1) + SU_S(2) \times SU(4)$$

we arrive at the quark composition of the ω, ϕ, Ψ, η, and η_C mesons:

$$\omega = \frac{p\bar{p} + n\bar{n}}{\sqrt{2}}, \quad \Phi = \lambda\bar{\lambda}, \quad \Psi = c\bar{c}, \tag{4}$$

$$\eta = \frac{2\lambda\bar{\lambda} - p\bar{p} - n\bar{n}}{\sqrt{6}}, \quad \eta_C = \frac{3c\bar{c} - p\bar{p} - n\bar{n} - \lambda\bar{\lambda}}{\sqrt{12}}. \tag{5}$$

Taking into account in the mass operator $\hat{M}$ only that term of the tensor operator $T^4_4 + T^8_8$, which is transformed like the C-even part of the regular representation, and writing down the $SU(3)$-breaking term in the usual form, we obtain the relation (D denotes the square of the mass of the D meson, etc.):

$$\begin{aligned} &3D = 2\eta_C + \eta, \quad 2D^* = \Psi + \omega, \quad D^* - \rho = D - \pi, \\ &F - D = K - \pi, \quad F^* - D^* = K^* - \rho. \end{aligned} \tag{6}$$

In this case, if $\Psi(3105)$ can be identified with $\Psi = c\bar{c}$ in (5), we obtain the following mass values: $m_D = 2.13$ GeV, $m_F = 2.19$ GeV, $m_{\eta C} = 2.58$ GeV, $m_{D^*} = 2.26$ GeV, and $m_{F^*} = 2.31$ GeV.

However, one cannot exclude the possibility that Ψ and Ψ' are excited states of a principal multiplet,[2,4] i.e., the following cases (7) and (8) are possible:

In case (7), $\eta_C = E(1420)$, which leads to the values 1.2, 1.29, 1.42, 1.49, and 2.16 GeV for m_D, m_F, m_{D^*}, m_{F^*}, and m_Ψ. In case (8) we have $\eta_C = \eta'(958)$, which yields $m_D = 0.85$ GeV, $m_F = 0.97$ GeV, $m_{D^*} = 1.13$ GeV, $m_{F^*} = 1.22$ GeV, and $m_\Psi = 1.78$ GeV. Refinement of the experimental situation in the regions of the masses (7) and (8) would make it possible to exclude the cases (7) and (8).

In conclusion, the author is deeply grateful to A. N. Leznov for initiating this work and for valuable advice, and to B. A. Arbuzov, V. V. Ezhela, M. V. Savel'ev, L. D. Solov'ev, and N. E. Tyurin for stimulating and useful discussions.

1. J. J. Aubert *et al.*, Phys. Rev. Lett. 33, 1404 (1974); J. E. Augustin *et al.*, *ibid.* 33, 1406 (1974); C. Bacci *et al.*, *ibid.* 33, 1408 (1974); G. S. Abrams *et al.*, *ibid.* 33, 1453 (1974).
2. M. K. Gaillart, B. W. Lee, and J. L. Rosner, Rev. Mod.

Phys. 47, 277 (1975).
[3]T. Appelquist and H. D. Politser, Phys. Rev. Lett. 34, 43 (1975).
[4]J. L. Rosner, Rapport. Talk at 17-th Internat. Conf. on High Energy Physics, London, 1974; V. V. Khrushchev, ZhETF Pis. Red. 21, 618 (1975) [JETP Lett. 21, 290 (1975)].