ELECTROMAGNETIC DECAYS OF MESONS IN THE QUARK MODEL

Ya. I. Azimov, V. V. Anisovich, A. A. Ansel'm, G. S. Danilov, and I. T. Dyatlov

A. F. Ioffe Physico-technical Institute, Academy of Sciences, U.S.S.R.

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The assumption of SU(6) symmetry[1] of strong interactions leads, as is well known, to a large number of relations between various matrix elements. In this note we wish to call attention to the fact that the application of SU(6) symmetry and of the quark model[2] to an analysis of electromagnetic decays of mesons makes it possible to make several preductions that could be experimentally verifiable even in the near future.

The probability of decay of a vector meson into a γ-quantum and a pseudoscalar meson is

$$\Gamma = \frac{4}{3}\mu^2 k^3 \qquad (1)$$

where μ is the magnetic moment of the transition and k the momentum of the produced particles. Expression (1) can be obtained either from a nonrelativistic consideration, using an interaction of the type $\vec{\mu}\,\vec{H}$ ($\vec{\mu}$ is the magnetic moment of the transition and $\vec{H}$ the magnetic field), or from the relativistic matrix element

$$\mu = \frac{1}{\sqrt{2q_0}}\frac{1}{\sqrt{2p_0}}\sqrt{\frac{2\pi}{k_0}}\,(2\mu)\varepsilon_{\alpha\beta\gamma\delta}e^V_\alpha e_\beta q_\gamma k_\gamma \qquad (2)$$

Here q, p, and k are the momenta of the vector meson, the pseudoscalar meson, and the photon, while e^V and e are the vector-meson and photon polarization vectors. The coefficients in (2) are chosen such that μ has in the nonrelativistic approximation the meaning of the magnetic moment of the transition.

The ratios of the transition matrix moments for various decays can be determined by the standard methods of SU(6) symmetry. One can use the quark model, assuming the magnetic moments of quarks to be proportional to their charges. The magnetic-moment operator of the i-th quark has then the form $\vec{\mu}_i = \mu_q Q_i \vec{\sigma}$, where Q_i takes on values 2/3, -1/3, and -1/3. The magnetic moments of different transitions are listed in the second column of the table[1]. It was assumed in the calculations that the physical particles φ and ω are the result of mixing, so that φ contains only strange quarks, and ω only non-strange quarks. Using the values of the magnetic moments and formula (1), we can easily calculate the relations between the probabilities of the various processes listed in the first column of the table. Inasmuch as the width of the decay $\omega \to \pi^0 + \gamma$ is known[3], we can also calculate the absolute values of the widths of other decays.

Reaction	μ/μ_q	Γ, MeV	Γ/Γ_{tot}, %
$\omega \to \pi^0 + \gamma$	1	1 ± 0.2	11 ± 1
$\omega \to \eta + \gamma$	$\frac{1}{3\sqrt{3}}$	$0.53 \cdot 10^{-2}$	0.06
$\rho^{\pm 0} \to \rho^{\pm 0} + \gamma$	$\frac{1}{3}$	0.1	0.1
$\rho^0 \to \eta + \gamma$	$\frac{1}{\sqrt{3}}$	0.037	0.03
$K^{*\pm} \to K^{\pm} + \gamma$	$\frac{1}{3}$	0.058	0.1
$\phi \to \eta + \gamma$	$\frac{2\sqrt{2}}{3\sqrt{3}}$	0.25	8
$K^{*0} \to K^0 + \gamma$	2/3	0.23	0.4

We see from the table that the magnetic moments of the transitions $\rho \to \pi + \gamma$ and $K^{*\pm} \to K^{\pm} + \gamma$ are one-third as large as the moment of the transition $\omega \to \pi^0 + \gamma$. As a result, even if we do not take the kinematic multipliers into account, the probabilities of these unobserved transitions are one order of magnitude smaller than the probability of the decay $\omega \to \pi^0 + \gamma$. Thus, SU(6) symmetry leads qualitatively to the same predictions for these decays as the hypothesis of A-parity conservation[4]. In this connection, particular interest is attached to the decay $\varphi \to \eta + \gamma$. From the point of view of A-parity conservation, this decay is forbidden, like the decay $\varphi \to \pi^0 + \gamma$. In the quark model the decay $\varphi \to \pi^0 + \gamma$ is also forbidden, since φ consists only of strange quarks, and the decay $\varphi \to \eta + \gamma$, as can be seen from the table, should proceed with rather high intensity. If the estimate given in the table is correct, then the decay $\varphi \to \eta + \gamma$ will apparently be experimentally observable even in the near future. Incidentally, it is possible that in spite of the lower relative probability, observation of the decays $K^* \to K + \gamma$ and $\rho \to \pi + \gamma$ will turn out to be even simpler than observation of $\varphi \to \eta + \gamma$.

In the framework of SU(6) symmetry, the parameter μ_q, which determines the magnetic moments of the quarks, is not known directly. In particular, arguments are advanced in [5] to show that μ_q is the effective magnetic moment of the quark, and depends on the character of the interaction binding the quarks inside the particles. In this connection, μ_q should have different values for mesons and baryons. Another point of view is possible, however, according to which μ_q always determines the quark's own magnetic moment. Similar assumptions, pertaining to the masses of quarks and connected with Zweig's original ideas[2], were made in a different paper and led to good agreement with experiment. If we determine the value of μ_q from the values of the magnetic moments of the nucleons, it is found to be equal to the proton magnetic moment, $\mu_q = \mu_p = 2.79e/2m_p$. We can then calculate the probability of the decay $\omega \to \pi^0 + \gamma$. The theoretical value $\Gamma = 1.2$ MeV is in suspiciously good agreement with the experimental $\Gamma_{exp} = (1.0 \pm 0.2)$ MeV[3]. An impression is thus gained that the value of the quark's magnetic moment does not depend on the character of the interaction binding the quarks in the particles, as would be expected in the non-relativistic model with weakly bound quarks.

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1) Some relations between the magnetic moments were obtained earlier[6] within the framework of SU(3) symmetry [the formulas in [6] contain misprints). In the case of SU(6) symmetry, the contribution of the F-coupling to the transition magnetic moments in question is equal to zero.