Interpretation of the $G(1590)$ meson

J. Lánik
Joint Institute for Nuclear Research

(Submitted 4 June 1985)
Pis'ma Zh. Eksp. Teor. Fiz. **42**, No. 3, 122–124 (10 August 1985)

Data on the decay of the $G(1590)$ meson can be explained satisfactorily even if this meson is not a gluonium but an $SU(3)_f$ singlet scalar quarkonium.

The report[1] of the discovery of a new scalar meson $G(1590)$ with a mass of 1592 ± 25 MeV, a width of 210 ± 40 MeV, and quantum numbers $I^G(J^{PC}) = 0^+(0^{++})$ was followed quickly by an attempt[2] to interpret this meson as a gluonium, i.e., as a bound state $|gg\rangle$ of gluons. The hypothesis of the gluon nature of the $G(1590)$ state is based on the experimentally observed suppression of the decay of the $G(1590)$ meson into the $\pi\pi$ and $K\bar{K}$ channels in comparison with the decay[1] $G(1590) \to \eta\eta$:

$$BR(G \to \pi^0\pi^0)/BR(G \to \eta\eta) < 1/3,$$
$$BR(G \to K\bar{K})/BR(G \to \eta\eta) < 0,6. \tag{1}$$

Gershteĭn *et al.*[2] suggested that the mechanism for the decay of the scalar gluonium into ordinary hadrons is based on diagrams of two possible types (Figs. 1a and 1b). They showed that if the diagram in Fig. 1b outweighs that in Fig. 1a, then it becomes possible to not only offer a reasonable explanation for the experimental data in (1) but also to predict the ratio

$$R \equiv BR(G \to \eta\eta')/BR(G \to \eta\eta) = 2-4. \tag{2}$$

Experimental data obtained subsequently[3] ($R_{\rm exp} = 2.7 \pm 0.8$) agree with this prediction.

 0021-3640/85/150149-03$01.00

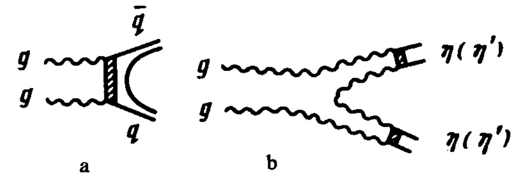

FIG. 1.

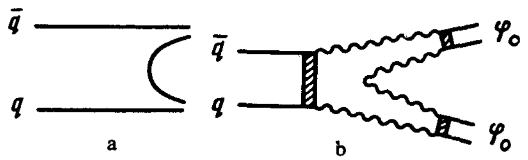

FIG. 2.

FIG. 1 and 2. The absence of $O(\alpha_S)$ suppressions of the transitions $\bar{q}q \leftrightarrow gg$ in the 0^+ and 0^- channels is indicated by the hatched regions (see Ref. 4, where a case is made for the existence of this strong coupling between quarks and gluons).

We will nevertheless show that all the existing experimental data on the decay[1,3] of $G(1590)$ can be explained satisfactorily even if this meson is not a gluonium but an $SU(3)_f$-singlet scalar quarkonium, i.e., even if its quark content is $(1/\sqrt{3})(u\bar{u}+d\bar{d}+s\bar{s})$. Such a state might belong, for example, to a scalar $^3P_0$ nonet or its radial excitation.

For this purpose, we work from the general $SU(3)_f$-symmetry relationship between the scalar singlet S_0 (quarkonium) and the pseudoscalar nonet $\phi_1(i=0.1,...,8)$, which is characterized by the phenomenological Lagrangian

$$\mathcal{L} = g_8 S_0 \sum_{i=1}^{8} \varphi_i^2 + g_0 S_0 \varphi_0^2 , \tag{3}$$

where g_8 and g_0 are the corresponding coupling constants. The first term in this Lagrangian corresponds to the $SU(3)_f$-symmetry diagram in Fig. 2a, while the second effectively reflects a coupling of the type in Fig. 2b. The diagrams in Fig. 2 are analogs of those in Fig. 1 for the case in which the initial scalar state S_0 is an $SU(3)_f$-singlet quarkonium. Since there are no suppressions of transitions between quark and gluon degrees of freedom in the scalar and pseudo-scalar channels (because of the strong influence of nonperturbative effects[4]), we can expect that the transitions in Fig. 2a are suppressed with respect to those in Fig. 2b, precisely as in the gluonium decay model[2] (Fig. 1). In Lagrangian (3) we thus find[1)] $g_8 \ll g_0$. Using the effective Lagrangian in (3) and a simple singlet-octet mixing of pseudoscalar states with a mixing angle θ, we can easily find the decay widths for the decay of the S_0 meson into a pair of pseudoscalar particles. For example,

$$\frac{BR(S_0 \to \eta\eta')}{BR(S_0 \to \eta\eta)} = \frac{1}{2}\left[\frac{(1-x)\sin 2\theta}{\cos^2\theta + x\sin^2\theta}\right]^2 \left(\frac{P_{\eta\eta'}}{P_{\eta\eta}}\right), \tag{4}$$

where $x = g_0/g_8$ and $P_{\eta\eta'}/P_{\eta\eta}$ is the ratio of phase volumes. Setting $\theta = -18°$ (see Ref. 5, where there are a detailed discussion and a bibliography), $x = 20$ amd $m_{S_0} = m_g = 1590$ MeV [identifying the S_0 state with the $G(1590)$ meson], we find from (4)

$$BR(S_0 \to \eta\eta')/BR(S_0 \to \eta\eta) = 3.37. \tag{5}$$

Analogously, we find

$$\begin{aligned} &BR(S_0 \to \pi^0\pi^0)/BR(S_0 \to \eta\eta) = 0.17, \\ &BR(S_0 \to K\bar{K})/BR(S_0 \to \eta\eta) = 0.55. \end{aligned} \tag{6}$$

These predictions agree satisfactorily with experimental data[1,3] on the decays of the $G(1590)$ meson.

We must add a few comments which follow from a comparison of the analogous diagrams in Figs. 1 and 2. In the first place, the previous calculations of the widths based on effective Lagrangian (3) are correct even in a gluon interpretation of the initial S_0 state. Conversely, the calculations carried out by Gershteĭn *et al.*, which they initially used for a gluonium[2] (Fig. 1), can also be applied to the scalar $SU(3)_f$-singlet quarkonium (Fig. 2).

It may thus be concluded that the data on the decay of the $G(1590)$ meson can be explained plausibly even if this meson is not a gluonium but an $SU(3)_f$-singlet quarkonium, strongly coupled with gluons in the 0^+ channel (or, in general, a mixture of such a quarkonium with a gluonium). As for the gluonium, we have previously argued[6] that such a particle might be difficult to observe, since it is a broad and poorly defined resonance.

I wish to thank S. S. Gershteĭn, A. T. Filippov, V. A. Mesheryakov, S. B. Gerasimov, and R. Lednitskiĭ for a discussion of these results and for useful comments. I also thank A. T. Filippov for reading and editing the Russian version of this manuscript.

[1)]S. S. Gershteĭn pointed out the need to consider the diagrams in Fig. 2b.

[1]F. Binon *et al.*, Yad. Fiz. **38**, 934 (1983) [Sov. J. Nucl. Phys. **38**, 561 (1983)]; Nuovo Cimento **78A**, 313 (1983).

[2]S. S. Gershteĭn, A. K. Likhoded, and Yu. D. Prokoshkin, Yad. Fiz. **39**, 251 (1984) [Sov. J. Nucl. Phys. **39**, 156 (1984)]; Z. Phys. **C24**, 305 (1984).

[3]F. Binon *et al.*, Yad. Fiz. **39**, 831 (1984) [Sov. J. Nucl. Phys. **39**, 526 (1984)]; Nuovo Cimento **80A**, 365 (1984).

[4]A. I. Vaĭnshteĭn *et al.*, Fiz. Elem. Chastits At. Yadra. **13**, 542 (1982) [Sov. J. Part. Nucl. **13**, 224 (1982)]; V. A. Novikov *et al.*, Nucl. Phys. **B191**, 301 01981).

[5]A. T. Filippov, Usp. Fiz. Nauk **137**, 201 (1982) [Sov. Phys. Usp. **25**, 371 (1982)].

[6]J. Ellis and J. Lánik, Phys. Lett. **150B**, 289 (1985); J. Lánik, Preprint E2-85-260, Dubna.

Translated by Dave Parsons