ON POSSIBLE ROLE OF NON-$Q\bar{Q}$ ADMIXTURES IN LIGHT (PSEUDO)SCALAR MESONS

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Content

- Preliminaries.
- Pseudoscalars: a bit backward before forward.
- Scalars without tears: From octets via nonets to a kind of decuplets(?).
- Discussion, prospects etc.

Motivations: The new data, new challenges

1.The UKQCD Collab.: new **unquenched** LQCD-calculation of the $J^{PC} = 0^{++}$ glueball

$${M_g}^{unqu} = 1795(60) vs {M_g}^{qu} = 1730(50)$$

2. The Belle Collab: First observation of ${B_s}^0 \rightarrow J/\Psi\eta'$ and $J/\Psi\eta$: the ratio of branchings is $0.73 \pm 0.14 \pm 0.02$, *vs* 1.04 ± 0.04 for a standard $\eta - \eta^{'}$ mixing angle.

3. The BES III Collab.:

(a) new measuremets of the width and mass of misterious $\eta(1405)$ (CL $\sim 10\sigma$),

(b) observation in the same region unusually strong violation of isotopic invariance much higher than the known effects of the $a(0)(980)-f(0)(980)$ mixing:

$$\frac{BR(\eta(1405) \to f_0(980)\pi^0 \to \pi^+\pi^-\pi^0)}{BR(\eta(1405) \to {a_0}^0(980)\pi^0 \to \eta\pi^0\pi^0)} =$$

$$= 17.9 \pm 4.2\%$$

We concentrate on the mass region $1.3 \div 1.7$ GeV occupied by the spin-zero $0^{\pm+}$ mesons. In each group of the positive (or negative) parity mesons there are three isoscalar mesons with similar masses which, in the presence of the nearly lying isotriplet and isodublet ones, suggest on the overpopulated nonet where a possible glueball (or multiquark state)is hidden within structures of the three isoscalar states.

I. Pseudoscalars:

ground state multiplet: [π,K,$\eta(.547)$,$\eta^{'}(.958)$]
radial-excited multiplet:[$\pi^{'}(1.3\pm.1)$,$K^{'}(4.1(4.6))$
$\eta(1.294)$,$\eta(1.474)$]+"extra" $\eta(1.405)$ GeV

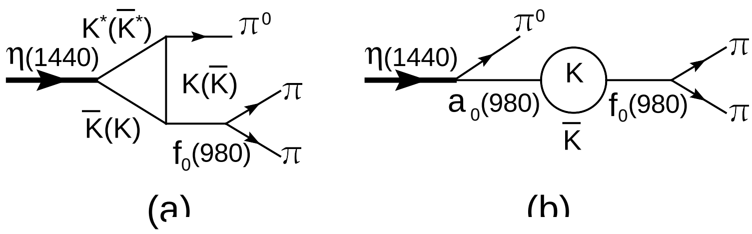
The obstacle preventing to carry out the direct diagonalization of the 5×5-matrix of all 5-isoscalar states is evidently insufficient accuracy of the measured masses of $\pi^{'}$- and $K^{'}$-radially-excited mesons. Therefore we have first to solve the inverse-problem and define the needed input mass-values for "direct"-problem. the qualitative estimation we apply the mass-formula derived by Schwinger long ago

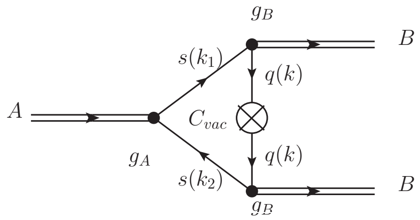
$$(\eta(1.47 vs 1.4) - \pi^{'})(\eta(1.29) - \pi^{'}) =$$

$$\frac{4}{3}(K^{'} - \pi^{'})(\eta(1.47 vs 1.4) + \eta(1.29) - 2K^{'})$$

though it enables to have only relation between $m(\pi^{'})$- and $m(K^{'})$-values.

We take alternatively two values for the higher mass of the radial-excited η,(1.4 and 1.474 GeV), discussed in the literature, and obtain a sequence of possible values $m(K^{'})$ for $m(\pi^{'})$ in the interval $1.3 \leq m(\pi^{'} \leq 1.45$. The solution consistent with the presence of the "extra"- (presumably, exotic) state $\eta(1405)$ was obtained under legitimate $\eta(1.474)$ and masses of $\pi'(K')$ lying in intervals $1.3 \leq m(\pi') \leq 1.345$ and $1.39 \leq m(K^{'}) \leq 1.42$. The solution consistent with absence the "extra"-$\eta's$ one obtains after "removing" $\eta(1.474)$ to higher mass interval and favorable occasion $m(K^{'} \simeq 1.4)$ and $m(\pi^{'} \simeq 1.345)$. The mentioned surprising violation of the isotopic invariance was discussed and its resolution was proposed (J.J.Wu a.o.,PRL,108,081803(2012) just for this last case via the special dynamical role of the kaon-loop-triangle diagrams in the $\eta(\sim 1.4) \to 3\pi$-decays. But the same mechanism may be in action, in our opinion, if the exotic $\eta(1405)$ is there and presents a new multi-quark $(3q3\bar{q})$-state (the question is under consideration)





The schematic diagrams for $\eta(1400) \to 3\pi$. Diagram (a) is driven by the ”anomalous” triangle singularity mechanism, while (b) gives contributions from the $a_0(980)$-$f_0(980)$ mixing.

II. Scalars

As is known, the long-lasting experimental and theoretical efforts have presently resulted in identification of a few scalar states with masses below $2GeV$, which can be interpreted as two meson nonets and a scalar glueball with the mixed valence quark and gluon configurations. In the states lying above 1 GeV the dominant configuration is, presumably, a conventional $q\bar{q}$ nonet mixed with the glueball.

Below 1 GeV, the states also form a nonet, where the central binding role is played by the $SU(3)_{c(f)}$ -triplet diquark clusters $(qq)_{\bar{3}}(\bar{q}\bar{q})_{3}$ in S-wave with some $q\bar{q}$ admixtures in P-wave and maybe less important glueball part in their state vectors. We follow below to earlier proposed scheme (S.G.2003) where flavor components have structure (with $\theta \simeq 10^{o}$)

$$|n_0^{'}(1474)\rangle = cos\theta|(1/\sqrt{2})(u\bar{u} - d\bar{d})\rangle +$$

$$+sin\theta|(1/\sqrt{2})((\bar{d}\bar{s})(ds) - (\bar{u}\bar{s})(us))\rangle,$$

$$|a_0^{'}(985)\rangle = -sin\theta|(1/\sqrt{2})(u\bar{u} - d\bar{d})\rangle +$$

$$+cos\theta|(1/\sqrt{2})((\bar{d}\bar{s})(ds) - (\bar{u}\bar{s})(us))\rangle.$$

The real,symmetric mass-matrix including possible presence and mixing with the glueball state acquires the following form

$$\hat{M}^2 = \begin{pmatrix} M_N^2 + 2A_Q & \sqrt{2}A_G & \sqrt{2}A_Q \\ \sqrt{2}A_G & M_G^2 & A_G \\ \sqrt{2}A_Q & A_G & M_S^2 + A_Q \end{pmatrix}$$

We start the treating of mass relations with the higher-mass, scalar 0^{++}-sector:

$$M_{a_0} = 1474 \pm 19, M_{K^*{}_0} = 1425 \pm 50$$

$$M_{f_0}(1) = 1370 \pm 50, M_{f_0}(2) = 1505 \pm 6,$$

$$M_{f_0}(3) = 1724 \pm 7$$

where all values are in MeV.

The ”bare” mass values M_N and M_S devoid of the strong annihilation contributions via

$$M_N = M_{a_0}, {M_S}^2 = 2{M_{K^*_0}}^2 - {M_{a_0}}^2 \quad (1)$$

Successively excluding unknown variables A_Q and A_G in favor of M_G, we solve numerically the last equation by varying remaining unknown M_G under constraint ${A_G}^2 \geq 0$. There is the nonzero solution for M_G and for $A_G = 0$ but none for $A_G > 0$. We have chosen as physically acceptable the value of the decoupled physical glueball mass

$M_G(ph) \simeq 1730\ MeV$ vis-a-vis $M_{f_0}(3) = 1724 \pm 7\ MeV$

The state vectors of the $f_0(1506)$ and $f_0(1370)$ are obtained by the diagonalizing the rest $2\times$ 2 matrix:

$$|f_0(1506)>= 0.868|N> +(-)0.496|S>$$

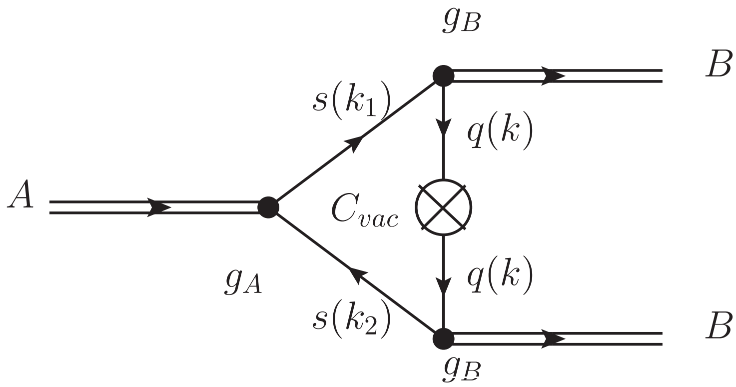
$$|f_0(1370)>= -(+)0.496|N> +0.868|S>$$

The choice of signs should be done on the physics ground. For description of the relations between the simplest strong decays $f_0(q\bar{q}) \rightarrow \pi\pi(K\bar{K}, etc.)$, we accept a kind of the vacuum $q_{vac}\bar{q}_{vac}$-pair "pick-up" process by the quarks bound in meson resonance to form the colorless hadrons in final state.

The vacuum pair participating in the process may appear as due to the vacuum auto-ionization by the moving color-charged dipole of quarks in the meson resonance. Otherwise, it can be thought as emerging due to the break of the ”string”, connecting and binding the valence quarks inside the meson resonance, accompanied by the production of the ”extra” $q\bar{q}$-pair . Heavier mass of the strange quark $m_s > m_{u(d)}$ invites to foresee some $SU(3)_{flavor}$ violation in the vertex including the effective coupling C_{vac} in the vertex of the $q\bar{q}(^3P_0)$-production off ”vacuum”-state.

$$\Sigma_{q=u,d,s} C_q^{vac} \cdot q\bar{q} = C_{u(d)}^{vac} \cdot (u\bar{u} + d\bar{d})$$

$$+ C_s^{vac} \cdot s\bar{s}; C_s^{vac} \leq C_{u(d)}^{vac}$$



With $y = C_s^{vac}/C_q^{vac}$ defined to be $y \simeq .32$ from experimental value

$$\Gamma(f_0(1500) \to K\bar{K})/\Gamma(f_0(1500) \to \pi\pi)$$

$$= .246 \pm .026$$

The ratios of other branchings are indicated in the Table 1 :

P_1P_2	$\pi\pi$	$\eta\eta$	$\eta^{'}\eta$
$f_0(mass)$	$\frac{BR(f_0(mass)\to P_1P_2)}{BR(f_0(mass)\to K\bar{K})}$		
$f_0(1370)\vert_{mod}$	.9	.09	—
$f_0(1370)\vert_{exp}$	1.0 ± 0.2	—	—
$f_0(1506)\vert_{mod}$	input	.6	—
$f_0(1506)\vert_{exp}$	4.1 ± 0.4	$.6\pm.1$	—
$f_0(1710)\vert_{mod}$	.9	.3	.067
$f_0(1710)\vert_{exp}$	$.41\pm0.13$	$.48\pm.13$	—

Table 1.

The sensitive check of results can provide the relation

$$\frac{\tilde{\Gamma}(J/\Psi\to\gamma+f_0(1506))}{\tilde{\Gamma}(J/\Psi\to\gamma+f_0(1370))}=\frac{(.868\sqrt{2}\pm.496}{(\mp.496\sqrt{2}+.868}$$

$$\approx 107(.22)$$

III. Concluding remarks

• Large amount of strange quarks in $f_0(1370)$ is favored by the experimental observation that the decay $J/\Psi \to \phi\pi\pi$ cannot be fitted without excitation of the $f_0(1370)$-resonance

• Dominance of the pion(s) decay mode of $f_0(1506)$ is in agreement with a large amount of the non-strange $q\bar{q}$-quarks in the state-vector of this resonance.

• The data of the BES Collab. seem to signal on a hierarchy of the radiative $(J/\Psi$ decay modes :

$$BR(J/\Psi \to \gamma f_0(1370)) \leq$$

$$BR(J/\Psi \to \gamma f_0(1506)) \leq$$

$$BR(J/\Psi \to \gamma f_0(1710))$$

that is in accord the glueball nature of $f_0(1710)$.

• As a base to have in mind some care let us list a few notes from current literature. Both the scalar and pseudoscalar sector is problematic up to now in spite of very large number of works devoted to problems connected with reliable experimental identification of glueballs and the theoretical description of their properties.In this respect we would especially mention rather recent (**and conflicting**) papers dealing with the situation of low-lying ($\sim 1.5 GeV$) pseudoscalar states and several reviews devoted to long-lasting searches of scalar glueball.

C. Amsler and A.Masoni, Review article "The $\eta(1405)$, $\eta(1475)$, $f_1(1420)$ and $f_1(1510)$", Phys.Lett. **B667**, 1 (2008).

$$\eta(1440) \Rightarrow \eta(1410) + \eta(1475)$$

D. Bugg,"Data on $J/\Psi \to \gamma(K^{\pm}K_s^0\pi^{\mp})$ and $\gamma(\eta\pi^+\pi^-)$", arXiv:hep-ex/0907.3015

$$\eta(1475)(\eta(1410)(?)) \Rightarrow \eta(1440)$$

"Study of $J/\Psi \to \gamma(\pi^+\pi^-\pi^+\pi^-)$", arXiv:hep-ex/0907.3015

$$f(0^{++};1710) \Rightarrow f(0^{++};1790)$$