ARE THE SCALAR MESONS $S^*(980)$, $\delta(980)$, $\kappa(1500)$ GLUKONIUMS ?

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ABSTRACT

The arguments in favour that the scalar mesons S^*, δ, κ are tightly connected with the longitudinal part of the $\bar{q}\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a q$ current are presented. These arguments are based on the consideration of the corresponding QCD sum rules. The natural explanation of the large $S^*-\kappa$ mass difference and coincidence of the S^*, δ meson masses is presented. The mass values $m_{S^*} \simeq m_\delta \simeq 1\,\mathrm{GeV}$ are obtained with the help of QCD sum rules.

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I. Introduction

The significant progress in understanding of the structure of the classical hadrons ($\pi, \rho, A_1, f \ldots$) is reached at present. This progress has been reached mainly due to such a powerful and fundamental method as that of QCD sum rules developed by Shifman Vainshtein and Zakharov [1]. The application of this method to charmonium [2], classical mesons [1,3,4], baryons [5,6], charmed hadrons [7,8] led to deeper understanding of the hadronic structure.

In the cases above the masses of the lowest resonances and corresponding coupling constants for "current-particle" transition had been found. The values various parameters (f_π, g_ρ, m_ρ) are determined in this approach [1] by the values of quark and gluon condensates. The breaking of the QCD asymptotic freedom in the cases considered above was connected with interactions with the mild vacuum fields. Therefore the breaking of the asymptotic freedom is under control.

In the present paper we apply the QCD-sum rules method to the investigation of the scalar mesons S^*, δ, κ . We show that these mesons can not be identified as the $\bar{q}q$ states. Note, that the question about quark context of the S^*, δ -mesons was considered for the first time in [9] in MIT bag model framework. The S^*, δ -mesons were identified with the $\bar{q}q\bar{q}q$ color - singlet system with $J^{PC} = 0^{++}$. The questions conserning the S^*, δ - mesons was discussed in detail in [10] too (see references therein). We give the arguments in favour that these mesons are tightly connected with the longitudinal part of the $\bar{q} G^a_{\mu\nu} \gamma_\nu \lambda^a q$ current (q - is the corresponding quark field $G^a_{\mu\nu}$ - is the gluon field). If this is the case then the following experimental facts receive their natural explanation: a) the coincidence of the S^* - δ meson masses; b) the rather large mass of the K-meson, which is the partner of S^*, δ -mesons in the 0^{++} nonet; c) the reasonable values for the S^*, δ -meson masses ($m_{S^*} = m_\delta \simeq 1\,GeV$).

II. The scalar mesons connected with the $\bar{q}q$ - current

In this section we consider the properties of scalar mesons which are connected tightly with the $\bar{q}q$ - current. We show with the help of QCD sum rules that the $S^*(980)$, $\delta(980)$, κ (1500) - mesons can't be strongly connected with the $\bar{q}q$ current because: a) the mass of the lowest resonance which is connected strongly with the $\bar{q}q$-current is 1,7 ÷ 1,8 GeV (note, that the $m_{S^*} = m_\delta$ = 0.98 GeV); b) the mass difference between the states with the isospins I = 0 and I = 1 must be $\gtrsim$ 200 ÷ 300 MeV (note, that ($m_{S^*} - m_\delta$) $\lesssim$ 10 MeV.)

As it was pointed out in the Introduction the breaking of the asymptotic freedom in a number of channels (vector, tensor, ...) is due to interactions with the mild vacuum fields. However in other channels (for example scalar, pseudoscalar) the QCD sum rules with only standard power corrections taken into account can not give reasonable mass scale in these channels [11]. The hard vacuum fields and direct instantons play a significant role here. The effects of these vacuum fluctuations are seen clearly in quark pseudoscalar channel with the π-meson quantum number, $j_\pi = \frac{i}{\sqrt{2}}(\bar{u}\gamma_5 u - \bar{d}\gamma_5 d)$ and the gluon scalar (pseudoscalar) channels [12]. The mass scale in both cases

is known: in the π -meson case the value of the matrix element $\langle 0|\bar{u}i\gamma_5 d|\pi\rangle = \frac{f_\pi m_\pi^2}{m_u + m_d} = -2\frac{\langle\bar{q}q\rangle}{f_\pi} \simeq 0.23\,GeV^2$ is known; in the gluon channel the corresponding low-energy theorem is known [12]. The analysis of these channels shows that the standard power corrections do not lead to reasonable results.

Some progress in understanding of corresponding channel properties with the help of QCD sum rules is reached in papers [13,14]. In these works the phenomenological model of the QCD-vacuum was proposed and the value of direct instanton contributions in these channels was estimated.

In particular, the value of the matrix element $\langle 0|\bar{u}i\gamma_5 d|\pi\rangle$ which was given in [13] is in a reasonable agreement with the value $-\frac{2\langle\bar{q}q\rangle}{f_\pi} \simeq 0.23\,GeV^2$. We use bellow the model [13] for the analysis of the $\bar{q}q$ -current (which is similar to the $J_\pi = \bar{q}i\gamma_5 q$ -current as for the direct instanton contributions)*.

Following the ideas the QCD sum rules [1] let us introduce the scalar current $J = \bar{u}d$ and corresponding correlator

$$i\int dx\, e^{iqx} \langle 0|T\{J(x)\, J(0)\}|0\rangle = S(q^2)$$

Here $S(q^2)$ is some scalar function obeing the standard dispersion relation. The asymptotic behaviour of $S(q^2)$ at $Q^2 = -q^2 \to \infty$ with the power and exponential contributions taken into account is determined in a standard way [1,13] and has the form (after

*) Note that the QCD sum rules for the $J = \bar{q}q$ current was investigated in [4] but the direct instanton contribution has not been taken into account. Such analysis, from our point of view, is wrong. Analogous investigation for the $J = \bar{q}i\gamma_5 q$ -current with the standard power corrections taken into account only can not give reasonable mass scale and leads to the wrong result.

"borelezation")*

$$\frac{8\pi^2}{3} f^2(0^+) e^{-m_{0^+}^2/M^2} = \left(\frac{\alpha_s(M^2)}{\alpha_s(\mu^2)}\right)^{8/9} M^4 \Big\{ 1 - e^{-S_0/M^2}\left(1+\frac{S_0}{M^2}\right) + \tag{1}$$

$$+ \frac{\pi^2}{3M^4}\left\langle \frac{\alpha_s}{\pi} G^2 \right\rangle + \frac{16}{9}\frac{\pi^3\alpha_s}{M^6}\left\langle \bar u \gamma_\mu \lambda^a u\, \bar u \gamma_\mu \lambda^a u \right\rangle -$$

$$- \frac{8\pi^3\alpha_s}{3M^6}\left\langle \bar u \sigma_{\mu\nu}\lambda^a d\, \bar d \sigma_{\mu\nu}\lambda^a u\right\rangle - \frac{8\pi^{3/2}}{3}\cdot\frac{M^5 \rho_c^3 n_c}{M^{*2}} e^{-M^2\rho_c^2} \Big\}$$

Here $m_{0^+}^2$ is the mass of the lowest resonance in the channel considered and S_0 determine the duality interval. The parameters: $n_c = 0.8\cdot 10^{-3}$ GeV^4 – the instanton density, $\rho_c = 1.6$ GeV^{-1} the critical radius and effective mass $M^* \simeq 0.17$ GeV are taken from the phenomenological model of QCD vacuum [13, 14]. The value $f(0^+)$ is determined by the matrix element

$$\langle 0 | \bar u d | 0^+ \rangle = f(0^+) \tag{2}$$

The factor $\left(\frac{\alpha_s(M)}{\alpha_s(\mu)}\right)^{8/9}$ in (1) is due to the anomalous dimension of the $\bar u d$ -current. Note that the exponential factor in (1) is connected with the "direct instanton contribution" [11, 13]. Just this contribution ensures the reasonable mass scale in π-meson channel and large value of the matrix element

$\langle 0 | \bar u i\gamma_5 d | \pi \rangle = f_\pi \cdot 1.8\,\text{GeV} \simeq 0.24\,\text{GeV}^2$

Note that one instanton contribution into the matrix element $\langle \bar u \gamma_\mu \lambda^a d\, \bar d \gamma_\mu \lambda^a u \rangle$ is zero so we use the factorization hypothesis [1] (see fig. 1.)

$$\langle \bar u \gamma_\mu \lambda^a d\, \bar d \gamma_\mu \lambda^a u \rangle = -\frac{16}{9}\langle \bar u u \rangle^2 \tag{3}$$

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*) The difference from π-meson sum rules [13] consists in the minus sign before the two last terms in (1).

As for the $\langle \bar u \sigma_{\mu\nu}\lambda^a d\, \bar d \sigma_{\mu\nu}\lambda^a u \rangle$ vacuum expectation it may be saturated both non-factorized (n.-f.) one instanton contribution (see fig. 2)

$$\langle \bar u \sigma_{\mu\nu}\lambda^a d\, \bar d \sigma_{\mu\nu}\lambda^a u \rangle_{n.f.} = \frac{24}{5\pi^2}\frac{n_c}{\rho_c^4 M^{*2}} \simeq 0.2\cdot 10^{-2}\,\text{GeV}^6 \tag{4}$$

and factorized (f.) contribution (see fig. 3)

$$\langle \bar u \sigma_{\mu\nu}\lambda^a d\, \bar d \sigma_{\mu\nu}\lambda^a u \rangle_{f} = \frac{16}{3}\langle \bar u u \rangle^2 \tag{5}$$

The treatment of QCD-sum rules (1) has been made in the following way. The value of M^2 in (1) has been varied in such limits that power correction at r.h.s. were between 5÷10% and 30÷35%. Then parameters $m_{0^+}^2$, S_0, $f(0^+)$ were chosen so that to obtain the best fit to the theoretical curve at r.h.s. in (1). As a result:

$$\begin{aligned} m^2(0^+) &\simeq 3\,\text{GeV}^2 \pm 15\% \\ S_0 &\simeq 4.5\,\text{GeV}^2 \\ f(0^+) &\simeq 0.65\,\text{GeV}^2 \end{aligned} \tag{6}$$

Note that the negative sign of the exponential term in sum rules (1) does not allow the resonance mass to be lower than $\simeq$ 1.7 GeV. So we can not associate δ -meson with $J = \bar u d$ current. Furthermore, if we try to saturate the sum rules of the type (1) by the S^*, δ -mesons then the direct instanton contribution will lead to the large admixture of the $\bar s s$ -state in the S^* -meson (analogously to the case of the η' -meson). This property leads to the large mass splitting of S^*, δ -mesons (~ 200÷300 MeV) and this contradicts to the experiment. So, we conclude that the mesons with the mass m^2 = 3÷3.5 GeV^2 (not the S^*, δ -mesons) are tightly connected with the $\bar q q$-current. This fact does not means, of course, that the matrix element $\langle 0 | \bar q q | S^* \rangle$ is zero. However, evidently $\langle 0|\bar{q}q|S^*,\delta\rangle \ll f(0^+) \simeq$ 0.65 GeV and the δ -meson contribution to the QCD sum rules (1) can be neglected as compared with the contribution of the $m^2 \sim 3$ GeV^2 meson.

That's why the $\bar{q}q$-current can not be used for the investigation of the S^*,δ -mesons. So, we would like to find another current $\tilde{J}$ such that the corresponding two-point function $i\int dx\, e^{iqx}\langle 0|T\{\tilde{J}(x)\tilde{J}(0)\}|0\rangle$ is saturated by the resonance with the mass $\sim$1 GeV. Then, by definition, the S^*,δ -mesons must be tightly connected with this $\tilde{J}$ -current and we can calculate the corresponding mass spectrum.

III. The $\tilde{J}=g\bar{q}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a q$ -current and QCD sum rules for the S^*,δ - mesons

Following the ideas outlined in the end of sect II consider the more complicated currents which are connected with the 0^{++} -channel. They are $\bar{q}\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a q$ and $\bar{q}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a q$. Note, that the "direct instanton contribution" play a significant role in the $\bar{q}\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a q$-channel. So, all the conclusions of sect. II concerning the rather large mass of the lowest resonance and large mass difference between the states with the isospin I = 0 and I = 1 are valid here as well. That's why the $\bar{q}\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a q$ current can not be used to investigate the properties of the S^*,δ -mesons.

Our proposal is as follows: the scalar S^*,δ,κ -mesons are tightly connected with the following currents:

$$S^* \sim \frac{g}{\sqrt{2}}\left(\bar{u}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a u + \bar{d}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a d\right)$$
$$\delta \sim \frac{g}{\sqrt{2}}\left(\bar{u}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a u - \bar{d}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a d\right) \tag{7}$$

$$\kappa \sim g\bar{s}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a u \tag{7}$$

In this section we show that the corresponding sum rules give the reasonable values of the S^*,δ meson masses and explain the reason for the coincidence of their masses. In next section we consider the role of the SU(3)-violating effects in the 0^{++} channel connected with the $\bar{q}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a q$ current. Moreover, we argue that there are rather large mass difference between the S^* and κ mesons.

Let us introduce the $\tilde{J}_\mu = g\bar{u}G^a_{\mu\nu}\sigma_{\nu\lambda}\lambda^a d$ current and corresponding two-point function

$$i\int dx\, e^{iqx}\langle 0|T\{\tilde{J}_\mu(x)\tilde{J}_\nu(0)\}|0\rangle = g_{\mu\nu}V(q^2) + q_\mu q_\nu \Pi(q^2) \tag{8}$$

Here $V(q^2)$, $\Pi(q^2)$ are some scalar functions satisfying to the usual dispersion relations. The physical states with the exotic quantum numbers 1^{-+} [12] contribute to the $V(q^2)$- spectral density only and states with the 0^{++}, 1^{-+} - quantum numbers contribute to the function $\Pi(q^2)$. Because we are interested in the 0^{++} channel we consider the $\Pi(q^2)$- function only. The asymptotic behaviour of $\Pi(q^2)$ at $Q^2=-q^2\to\infty$ is determined in a standard way [1] and has the form (after "borelization")*

*) The $\langle G^3\rangle$- contributions ~~is eliminated~~ cancel in the sum of the diagrams. Note, that we do not calculate the diagrams like fig. (8) in the $1/M^8$ term, because these contributions can be neglected as compared with the contributions of the diagrams like those on fig. 7.

$$\frac{1}{\pi}\frac{1}{M^2}\int \operatorname{Im}\Pi(s)e^{-s/M^2}ds = \frac{\alpha_s}{20\pi^3}M^4\Big\{1-\frac{10}{9}\frac{\pi^3}{\alpha_s M^4}\langle\frac{\alpha_s}{\pi}G^2\rangle + \qquad (9)$$

$$+\frac{640}{9}\frac{\pi^4}{\alpha_s M^6}\langle\alpha_s^{1/2}\bar u u\rangle^2 - \frac{800}{2^7}\frac{\pi^4}{\alpha_s^{1/2}}\langle\alpha_s^{1/2}\bar u u\rangle\langle ig\bar d\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a d\rangle\frac{1}{M^8}\Big\}$$

Here $\langle\frac{\alpha_s}{\pi}G^2\rangle = 1.2\cdot 10^{-2}\,GeV^4$, $\langle\alpha_s^{1/2}\bar u u\rangle^2 = 1.83\cdot 10^{-4}\,GeV^6$ [1]

$\langle ig\bar d\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a d\rangle \simeq (1\div 3)10^{-2}\,GeV^5$ [14, 15]. The power corrections in the expression (9) are connected with the diagrams in figs. 4-7 correspondingly. We choose the following form for the $\operatorname{Im}\Pi(s)$ - spectral density:

$$\operatorname{Im}\Pi(s) = \pi f_\delta^2\delta(s-m_\delta^2) + \theta(s-s_0)\Big(\frac{\alpha_s}{20\pi^3}s^2 - \frac{1}{18}\langle\frac{\alpha_s}{\pi}G^2\rangle\Big) \qquad (10)$$

Note, that the analogous parametrization of the spectral density gives the reasonable results in other sum rules. The parameter s_0 determines the duality interval in the corresponding correlator. The value f_δ is determined by the matrix element:

$$\langle 0|\bar u G^a_{\mu\nu}\gamma_\nu\lambda^a d|\delta\rangle = f_\delta\cdot q_\mu \qquad (11)$$

From (9), (10) one has*

$$f_\delta^2 e^{-m_\delta^2/M^2} = \frac{\alpha_s}{20\pi^3}M^6\Big\{1-e^{-s_0/M^2}\Big(1+\frac{s_0}{M^2}+\frac{1}{2}\frac{s_0^2}{M^4}\Big) - \qquad (12)$$

$$-\frac{10}{9}\frac{\pi^3}{\alpha_s M^4}\big(1-e^{-s_0/M^2}\big)\langle\frac{\alpha_s}{\pi}G^2\rangle + \frac{640}{9}\frac{\pi^4}{\alpha_s M^6}\langle\alpha_s^{1/2}\bar u u\rangle^2 - \frac{800\pi^4}{2^7\alpha_s^{1/2}M^8}\langle\alpha_s^{1/2}\bar u u\rangle\langle ig\bar d\sigma G d\rangle\Big\}$$

The standard treatment of (12) (see sect II) gives:

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*) The contributions of the higher mass states in the 0^{++} and 1^{-+} channels are taken into account with help of continuum term in (10). This contribution is determined by the value of s_0.

$$f_\delta \simeq (0.33\,GeV)^3$$
$$m_\delta^2 = 1\,GeV^2 \pm 10\% \qquad (13)$$
$$s_0 \simeq (1.6\div 1.7)\,GeV^2$$

It is worth nothing that the value $m_\delta \simeq 1\,GeV$ does not contradict to the experimental data.

Let us remind some results for the vector [1] and tensor [3,4] channels before discussing the consequences of the proposal (7). The corresponding sum rules reproduce correctly the proporties of these mesons. In the $\bar q\gamma_\mu q$ and $\bar q\gamma_\mu\overleftrightarrow{D}_\nu q$ -channels (describing $\rho-\omega-\varphi$ and $f-A_2-f'$ - mesons respectively) the "direct instanton contributions" are absent [11] so the $\bar s s$-state splits off and corresponds to the φ, f'-mesons*. At the same time the $\bar s s$-term in the f [3,4] and ω [1] mesons is absent. If the intermediate vacuum state is dominant in the matrix element $\langle\bar q\gamma_\mu\lambda^a q\bar q\gamma_\mu\lambda^a q\rangle$ then the QCD sum rules for the ρ and ω-mesons becomes identical. As a result, the ρ -and ω --masses coincide. The accuracy of this approximation is about $\sim 6\%$ [1]. Note, that the analogous proporties in the $\bar q\gamma_\mu\overleftrightarrow{D}_\nu q\ (2^+)$ -channel take place: $m_f \simeq m_{A_2}$; $f'\sim\bar s s$

Moreover the longitudinal part of the current $\bar q G^a_{\mu\nu}\gamma_\nu\lambda^a q$ have the same properties. This is because of chirality properties of this current and absence of the "direct instanton contributions" in this channel. So, the $\bar s G^a_{\mu\nu}\gamma_\nu\lambda^a s$ -term splits off.

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*) In other channels, for example, $\bar q\gamma_5 q$, the $\bar s\gamma_5 s$ -term does not splits off because the direct instanton contribution is present in this channel. Indeed, the η and η' mesons have the admixture of the $\bar s\gamma_5 s$ term.

At the same time the $\bar{u}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a u \pm \bar{d}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a d$ -states correspond to the S^*, δ mesons. The nearly coicidence of the S^*, δ -masses is a consequence of identity of the corresponding sum rules as far as the factorization hypothesis for the matrix element $<\bar{q}\gamma_\mu q\bar{q}\gamma_\mu q>$ is valid.

III. The SU(3)-symmetry - breaking effects.

Let us introduce the current $\tilde{J}_\mu = g\bar{s}G^a_{\mu\nu}\sigma_{\mu\nu}\lambda^a u$ containing the $\bar{s}$-quark field and connect it with the K(1500)-meson. In this case the terms

$$\frac{m_s^2}{M^2},\ \frac{m_s<\bar{s}s>}{M^4},\ \frac{m_s<\bar{s}\sigma_{\mu\nu}G^a_{\mu\nu}\lambda^a s>}{M^6},\ \frac{m_s<\bar{s}G^2_{\mu\nu}s>}{M^6},\ \frac{<\bar{u}u>(<\bar{s}s>-<\bar{u}u>)}{M^6}$$

should be added to the r.h.s. of the expression (9). These contributions ensure the different masses for the K(1500) and δ (980) mesons. The SU(3) symmetry breaking effects are mainly due to the $m_s<\bar{s}G^a_{\mu\nu}s>$, $<\bar{u}u>(<\bar{s}s>-<\bar{u}u>)$ matrix element contributions. That's why we keep only these terms for what follows.

Therefore:

$$\frac{1}{\pi}\int[\mathrm{Im}\,\Pi_{\delta(980)}(s)-\mathrm{Im}\,\Pi_{K(1500)}(s)]e^{-s/M^2}ds = \qquad (14)$$
$$= +\frac{32}{9}\pi<\alpha_s^{1/2}\bar{u}u>(<\alpha_s^{1/2}\bar{u}u>-<\alpha_s^{1/2}\bar{s}s>)-\frac{\pi^2}{3}m_s<\bar{s}\frac{\alpha_s}{\pi}G^a_{\mu\nu}\lambda^a G^b_{\mu\nu}\lambda^b s>\frac{1}{M^2}$$

We use below the model [14] to estimate matrix element $<\bar{s}G^a_{\mu\nu}G^a_{\mu\nu}s>$. It was proposed in [14] that the vacuum expectation arises due to the instantons with the parameters: $n_c \simeq 0.8\cdot10^{-3}$ GeV^4, ρ_c = 1.6 GeV^{-1}, M^* = 0.17 GeV. This proposal concerning the QCD-vacuum structure give a reasonable agreement with the well known values of $<G^2_{\mu\nu}>$ and $<\bar{q}q>$ [14] and with the matrix ele-

ments in the gluon and π -meson channels [13]. The results:

$$<\bar{s}\frac{\alpha_s}{\pi}G^a_{\mu\nu}G^a_{\mu\nu}s>_{n.f.} = -\frac{32}{5\pi^2}\frac{n_c}{\rho_c^4 M^*} = -4.\ldots\cdot10^{-4}\,\mathrm{GeV}^7$$
$$<\bar{s}\frac{\alpha_s}{\pi}G^a_{\mu\nu}G^a_{\mu\nu}s>_{f.} = <\frac{\alpha_s}{\pi}G^a_{\mu\nu}G^a_{\mu\nu}><\bar{s}s> \qquad (15)$$

In order to estimate the matrix element $<\bar{u}u>-<\bar{s}s>$ let us assume that*)

$$|<\bar{u}u>|-|<\bar{s}s>| \simeq \left(\frac{1}{3}\div\frac{1}{10}\right)|<\bar{u}u>|. \qquad (16)$$

Let's carry out the following estimate for the mass of the K-meson. In the vector channel $\bar{q}\gamma_\mu q$ the $K^*-\rho$ mass spliting was connected with the value of the matrix element $<\bar{s}s>$. In the 1^--case this correction is ~ 30% of free loop value at $M^2(1^-)$ $\simeq$ 0,5 GeV^2 [1]. In our 0^+-case the $<\bar{s}G^a_{\mu\nu}G^a_{\mu\nu}s>$ correction (15) is ~ 30% at $M^2(0^+) \simeq$ 1.2 GeV^2 and the $(<\bar{s}s>-<\bar{u}u>)$ correction (15) is ~ 30% at $M^2(0^+) \simeq$ 1.15÷1.6 GeV^2 (see (9), (14)-(16). The mass spliting in the nonet is connected with the mass scale of the SU(3)-symmetry breaking. So the ratio of the mass spliting in the 0^+-channel and the one in the 1^--channel is ~ $M^2(0^+)/M^2(1^-)$

$$\left(\frac{m_K^2-m_\delta^2}{m_\delta^2}\right)\bigg/\left(\frac{m_{K^*}^2-m_\rho^2}{m_\rho^2}\right) \simeq \frac{M^2(0^+)}{M^2(1^-)} \sim \frac{1.5\,\mathrm{GeV}^2}{0.5\,\mathrm{GeV}^2} \sim 3 \qquad (17)$$

$$m_K \simeq 1.3\div1.4\,\mathrm{GeV}$$

The analogous estimate can be obtained in an another way. Suppose that $f_\delta \simeq f_{K(1500)}$ and use (13)-(16) to obtain:

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*) Note that the smaller value of $|<\bar{s}s>|$ in comparison with the $|<\bar{u}u>|$ (~ 20÷30%) is preferred because it gives the correct value for the ratio $f_K/f_\pi \simeq$ 1.2 [16]. The theoretical arguments in favour of the smaller value $|<\bar{s}s>|$ are given also in [17] (see also [11,5]).

$$e^{-m_K^2/\bar{M}^2} - e^{-m_S^2/\bar{M}^2} \simeq \frac{1}{f_S^2}\Big\{\frac{32}{9}\pi\langle\alpha_s^{1/2}\bar{u}u\rangle\left(\alpha_s^{1/2}\langle\bar{s}s\rangle - \langle\alpha_s^{1/2}\bar{u}u\rangle\right) + \frac{\pi^3}{3} m_s \frac{1}{\bar{M}^2}\langle\bar{s}\,G_{\mu\nu}^a\lambda^a G_{\mu\nu}^b\lambda^b s\rangle\Big\} \qquad (18)$$

Here $\bar{M}^2 \simeq 2.5 \div 3$ GeV^2 - is the value of M^2 when the power corrections in the QCD sum rules are $\sim 10 \div 30\%$. From (18) we obtain that $m_K \sim 1.4 \div 1.5$ GeV in accordance with the estimate (17).

We realize that the above estimates (17),(18) are not very precize because of large uncertainties in the matrix elements (15),(16).

From our point of view, however, the large SU(3)-symmetry breaking effect are present really in the 0^+-channel. The corresponding strengthening is connected with the large value of vacuum expectations (15),(16).

Therefore, with all the above considerations we expect that the 0^+ state connected with the $\bar{s}\,G_{\mu\nu}^a\gamma_\nu\lambda^a s$ current splits off and has the large mass $\sim 1.8 \div 2$ GeV. The characteristic property of this meson is the presence of $K\bar{K}$-decay mode and the absence of $\pi\pi$-decay mode (analogously to the case of the φ -meson).

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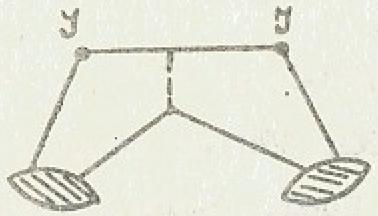


Fig.1

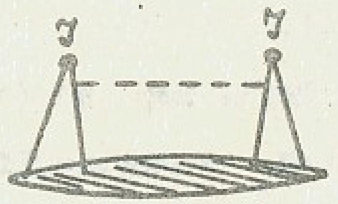


Fig.2

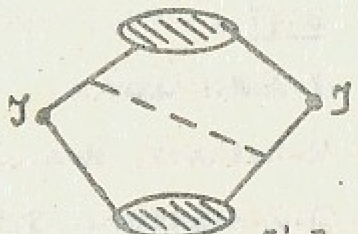
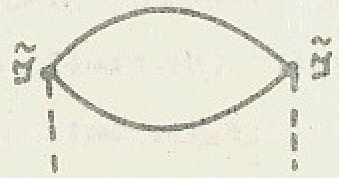


Fig.3

Fig.4



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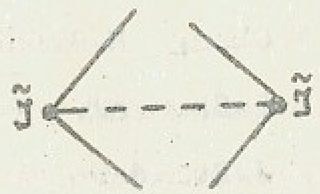

Fig.6

Fig.7a

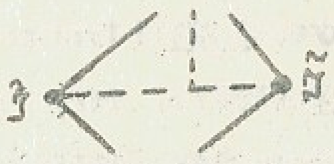

Fig.7b

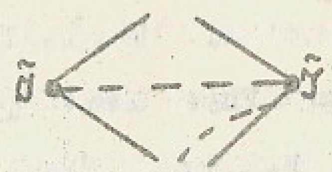

Fig.7c

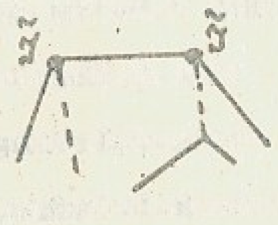

Fig.8

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СКАЛЯРНЫЕ МЕЗОНЫ S^*, δ, κ ГЛЮОНИИ?

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