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# A Duality Scheme with the Quark-Model Hadron Spectrum and the $\delta(980)$ and $S^*$ (975) Scalar Mesons

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The scalar mesons $\delta(980)$ and $S^*$ (975), as $q\bar{q}$ systems, are discussed in a duality scheme with the harmonic-oscillator spectrum of $SU(6)\otimes O(3)_L$ multiplets.

The scalar mesons $\delta(980)$ and $S^*(975)$ were a cause of problems in the scalar $SU(3)$ nonet. The near mass-degeneracy between them was difficult to understand. Similarly, the mass difference $m(\kappa(1350))-m(\delta)$ was ununderstandable. Such problems have, however, now solved by the unitarized quark model.[1] In spite of their unconventional experimental properties, the scalar mesons $\delta(980)$, $\varepsilon(1300)$, $\kappa(1350)$ and $S^*(975)$[2] can be understood as the unitarized remnants of conventional $q\bar{q}$ states.

The scalar mesons $\delta$, $\varepsilon$, $\kappa$ and $S^*$ are interesting objects also in the recently proposed duality scheme with the quark-model hadron spectrum (the harmonic-oscillator spectrum of $SU(6)\otimes O(3)_L$ multiplets).[3] We discussed the scalar mesons in this scheme in an early work,[4] on the viewpoint that the $\delta'(\sim 1300)$[5] and $\varepsilon'(\sim 1550)$[6] in addition to the $\varepsilon$ and $\kappa$ were components of a scalar nonet,[*] and the lower-mass and narrow $\delta$ and $S^*$ were assumed to be $q\bar{q}q\bar{q}$ mesons, according to Jaffe.[7] In this note, we discuss the $\delta$ and $S^*$, as $q\bar{q}$ mesons, in the duality scheme.

Now, we consider the $K^-K^0\to K^-K^0$ scattering, where the $u$-channel is exotic. The duality relation, which is taken as the working hypothesis here, is

$$\sum_{a\in N} R_a^{(s)}(t)\,|_{t=m_{N'}^2} = \sum_{b\in N'} R_b^{(t)}(s)\,|_{s=m_N^2}, \qquad N, N'=0, 1, 2, \ldots. \tag{1}$$

Here $N(N')$ is the $s$-($t$-)channel resonance family with a fixed total number of quanta of oscillator excitations, $N(N')$, (denoted by the total number, for economy of notations). $R_a^{(s)}(t)\,(R_b^{(t)}(s))$ is the residue of the contribution of $s$-($t$-)channel resonance $a(b)$ to the scattering amplitude, in the narrow-resonance approximation. And $m_N^2(m_{N'}^2)$ is defined to be the average squared-mass of $N(N')$. The duality constraint (1) is for $s>0$ and $t>0$, where the contributions of poles dominate and the effects of Regge cuts are small.[8] Therefore the duality (1) will be worth-while to study the partial decay widths

[*] As for the $\delta'$ and $\varepsilon'$, none of them is established with certainty.

or the corresponding coupling constants, though it can not explain the unconventional features of $m_\delta$ and $m_{S^*}$.

The $[A_2, \delta]=[\phi]$, which is the relation (1) in the case $(N, N')=(1, 0)$, gives a restriction on the $g^2_{\delta K\bar{K}}$, defined as in Ref. 4), when observed $\Gamma_{A_2K\bar{K}}$ and $\Gamma_{\phi K\bar{K}}$ are taken as input in addition to relevant masses. The $[\rho]=[f', (\varepsilon, S^*)]$, the relation in the case $(N, N')=(0, 1)$, provides us with a restriction on the $(\Gamma_{\varepsilon K\bar{K}}/q_1+g^2_{S^*K\bar{K}}m^2_{S^*}/m^2_\varepsilon)$ similarly, where $q_1=\sqrt{m^2_\varepsilon-4m^2_K}/2$. The average squared-masses of $\{A_2, \delta\}$ and $\{f', (\varepsilon, S^*)\}$ are taken as $m^2_{A_2}$ and $m^2_{f'}$ respectively, as the $A_2$ dominates in the left-hand side of the relation $[A_2, \delta]=[\phi]$ and the $f'$ does in the right-hand side of $[\rho]=[f', (\varepsilon, S^*)]$.[9]

With experimental data[2] of $\Gamma_{A_2K\bar{K}}$, $\Gamma_{\phi K\bar{K}}$, $\Gamma_{f'K\bar{K}}$, $m_{A_2}$, $m_{f'}$, $m_\delta$, $m_\varepsilon$, $m_{S^*}$, $m_\phi$, $m_\rho$ and $m_K$, the predicted $g^2_{\delta K\bar{K}}$ and $(\Gamma_{\varepsilon K\bar{K}}/q_1+g^2_{S^*K\bar{K}}m^2_{S^*}/m^2_\varepsilon)$ from these duality relations are

$$g^2_{\delta K\bar{K}}=0.70\pm0.50, \qquad (\Gamma_{\varepsilon K\bar{K}}/q_1+g^2_{S^*K\bar{K}}m^2_{S^*}/m^2_\varepsilon)=-3.5\sim0.55. \tag{2}$$

It is noted that the information on the $f^2_{\rho K\bar{K}}$, needed to the $[\rho]=[f', (\varepsilon, S^*)]$, is obtained from the $[\rho]=[\phi]$, the relation of (1) in the case $(N, N')=(0, 0)$, which is found to be in good agreement with experiments.[9]

The value of $g^2_{\delta K\bar{K}}$ in Eq. (2) gives

$$g^2_8=1.17\pm0.83, \tag{3}$$

if the $SU(3)$ $0^+\to0^-0^-$ coupling is assumed. And this value of Eq. (3) implies

$$\Gamma_{\delta\eta\pi}=150\pm110 \text{ MeV}. \tag{4}$$

The prediction (4), $\sim$150 MeV, is consistent with that from the unitarized quark model,[1] which is asserted to be larger than apparent peak width. While, the latter in Eq. (2) is meaningful only when small $\Gamma_{f'K\bar{K}}$ is established.

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