Candidates for Chiral Particles

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I. Introduction

The covariant level-classification scheme of hadrons with $U(12)_{SF} \times O(3, 1)_L$ symmetry has been proposed, which gives a covariant quark representation for composite hadrons with definite Lorentz and chiral transformation properties.

Here we try to assign all the known light-unflavored and strange mesons with masses below ~ 1.8 GeV to qq nonets which are predicted to exist in the covariant level-classification scheme. Then even the two exotic mesons, $\pi_1(1400)$ and $\pi_1(1600)$, with $J^{PC} = 1^{-+}$ recently reported are regarded as the chiral qq states, which never appear in any nonrelativistic quark model.

II. Listing of observed mesons below ~ 1.8 GeV

We make a list of all the observed light-unflavored and strange mesons with masses below ~1.8 GeV, which are expected to be composed of light-quarks (u, d, s), according to the Particle Data Group 2002 edition except for the following mesons:

(1) $\eta(1410)$ and $\eta(1475)$

The PDG entry $\eta(1440)$ is considered as representing the above two psedoscalars. The former decays into $KK\pi$ mainly through $a_0(980)\pi$ and the latter mainly through $K^*(892)K$.

(2) $\kappa(800)$

In recent years, evidence for the existence of the $\kappa(700\sim900)$ meson has been

reported in the reanalyses of $K\pi$ scattering phase shift data, the Dalitz-plot analysis of the decay $D^+ \to K^-\pi^+\pi^+$ by the Fermilab E791 Collaboration and the analysis of the decay $J/\psi \to K^*(892)K\pi$ by the BES Collaboration. We consider here this $\kappa(800)$ to be a genuine resonance.

(3) $\rho(1250)$ and $\omega(1200)$

There is some experimental evidence for the $\rho(1250)$ reported by the OMEGA, LASS and OBELIX Collaborations. The existence of the $\omega(1200)$ is claimed in the analysis of the $e^+e^- \to \pi^+\pi^-\pi^0$ cross section by the SND Collaboration. We accept the existence of these vector mesons as true.

The resulting meson listing is shown in the table.

Table

The Particle Listing of Mesons Below ~ 1.8 GeV

J^{PC}	Mesons				
0^{-+}	π	$\pi(1300)$	$\pi(1800)$		
	η	$\eta(1295)$	$\eta(1410)$	$\eta(1760)$	
	$\eta'(958)$	$\eta(1475)$			
	K	$K(1460)$	$K(1830)$		
0^{++}	$a_0(980)$	$a_0(1450)$			
	$\sigma(600)$	$f_0(1370)$	$f_0(1500)$		
	$f_0(980)$	$f_0(1710)$			
	$\kappa(800)$	$K_0^*(1430)$			
1^{--}	$\rho(770)$	$\rho(1250)$	$\rho(1450)$	$\rho(1700)$	$\rho(1900)$
	$\omega(782)$	$\omega(1200)$	$\omega(1420)$	$\omega(1650)$	
	$\phi(1020)$	$\phi(1680)$			
	$K^*(892)$	$K^*(1410)$	$K^*(1680)$		
1^{+-}	$b_1(1235)$				
	$h_1(1170)$	$h_1(1595)$			
	$h_1(1380)$				
	$K_1(1270)$	$K_1(1650)$			
1^{++}	$a_1(1260)$	$a_1(1640)$			
	$f_1(1285)$				
	$f_1(1420)$	$f_1(1510)$			
	$K_1(1400)$				
1^{-+}	$\pi_1(1400)$	$\pi_1(1600)$			

2^{++}	$a_2(1320)$	$a_2(1700)$		
	$f_2(1270)$	$f_2(1430)$	$f_2(1565)$	$f_2(1640)$
	$f_2'(1525)$	$f_2(1810)$		
	$K_2^*(1430)$	$K_2(1580)$		
2^{-+}	$\pi_2(1670)$	[redacted]		
	$\eta_2(1645)$	$\eta_2(1870)$		
	$K_2(1770)$			
2^{--}	$K_2(1820)$			
3^{--}	$\rho_3(1690)$	$\rho_3(1990)$		
	$\omega_3(1670)$			
	$\phi_3(1850)$			
	$K_3^*(1780)$			

• Data are taken from PDG 2002, except for the $\kappa(800)$.

Here we make some comments on this meson listing:

(1) There is at least an extra psedoscalar meson, which has no place in qq nonets within the framework of any nonrelativistic quark model, in the isoscalar sector.

(2) We have several scalar mesons which are difficult to be interpreted as nonrelativistic qq states.

(3) There are supernumerary vector states with the conventional J^{PC} quantum numbers in the nonrelativistic classification of qq mesons.

(4) We have two mesons with exotic quantum numbers $I^G(J^{PC}) = 1^-(1^{-+})$ which are not accessible to the nonrelativistic qq system.

(5) Some tensor mesons with $J^{PC} = 2^{++}$ seem unable to be nonrelativistic qq states.

III. Possible assignments for the listed mesons in the covariant level-classification scheme of hadrons

In the covariant level-classification scheme of hadrons there exist additional qq nonets, which do not appear in any nonrelativistic quark model, with various J^{PC} quantum numbers, including exotic ones. The qq nonets with the orbital angular momentum L = 0, 1, 2 are predicted to contain the following J^{PC} quantum numbers:

- L = 0 nonets

  $J^{PC} = 0^{-+}$ (2), 1^{--} (2), 0^{++}, $\boxed{0^{+-}}$, 1^{++}, 1^{+-}

- L = 1 nonets

  $J^{PC} = 1^{+-}$ (2), 0^{++} (2), 1^{++} (2), 2^{++} (2), $\boxed{0^{--}}$,
  0^{-+}, 1^{--} (2), $\boxed{1^{-+}\ (2)}$, 2^{--}, 2^{-+}

- $L = 2$ nonets

$J^{PC} = 2^{-+}(2),\ 1^{--}(2),\ 2^{--}(2),\ 3^{--}(2),\ 1^{++},$
$1^{+-},\ 2^{++}(2),\ \boxed{2^{+-}(2)},\ 3^{++},\ 3^{+-}$

Here we assign all the listed mesons to these qq nonets and the radial excitation of $L = 0$ nonets, resorting to their quantum numbers and masses. The resulting assignments are shown in the table.

Table

From the table we see that there is enough room to be assigned, although their assignments are ambiguous. It is worth while mentioning that there are suitable places for the two exotic 1^{-+} mesons, $\pi_1(1400)$ and $\pi_1(1600)$, in the covariant level-classification scheme.

Possible Assignments for All of the Known Mesons Below ~ 1.8 GeV in the Covariant Level Classification Scheme of Hadrons

	P	S	$\widetilde{P}$	$\widetilde{S}$	V	A	$\widetilde{V}$	$\widetilde{B}$
	1^1S_0				1^3S_1			
	0^{-+}	0^{++}	0^{-+}	0^{+-}	1^{--}	1^{++}	1^{--}	1^{+-}
$L=0$	π	$a_0(980)$	$\pi(1300)$		$\rho(770)$		$\rho(1250)$	
	η	$\sigma(600)$	$\eta(1295)$		$\omega(782)$		$\omega(1200)$	
	$\eta'(958)$	$f_0(980)$	$\eta(1475)$		$\phi(1020)$			
	K	$\kappa(800)$	$K(1460)$		$K^*(892)$		$K^*(1410)$	

$L=1$					1^3P_0			
					0^{++}	0^{--}	0^{++}	0^{-+}
					$a_0(1450)$ $f_0(1370)$ $f_0(1710)$ $K_0^*(1430)$		$f_0(1500)$	$\eta(1410)$
	1^1P_1				1^3P_1			
	1^{+-}	1^{--}	1^{+-}	1^{-+}	1^{++}	1^{--}	1^{++}	1^{-+}
	$b_1(1235)$ $h_1(1170)$ $h_1(1380)$ $K_1(1270)$		$h_1(1595)$ $K_1(1650)$	$\pi_1(1600)$	$a_1(1260)$ $f_1(1285)$ $f_1(1420)$ $K_1(1400)$		$f_1(1510)$	$\pi_1(1400)$
					1^3P_2			
					2^{++}	2^{--}	2^{++}	2^{-+}
					$a_2(1320)$ $f_2(1270)$ $f_2'(1525)$ $K_2^*(1430)$		$f_2(1430)$ $K_2(1580)$	

	P	S	$\widetilde{P}$	$\widetilde{S}$	V	A	$\widetilde{V}$	$\widetilde{B}$
	2^1S_0				2^3S_1			
	0^{-+}	0^{++}	0^{-+}	0^{+-}	1^{--}	1^{++}	1^{--}	1^{+-}
$L=0$			$\pi(1800)$ $\eta(1760)$ $K(1830)$		$\rho(1450)$ $\omega(1420)$ $\phi(1680)$ $K^*(1680)$			
$L=2$					1^3D_1			
					1^{--}	1^{++}	1^{--}	1^{+-}
					$\rho(1700)$ $\omega(1650)$	$a_1(1640)$	$\rho(1900)$	
	1^1D_2				1^3D_2			
	2^{-+}	2^{++}	2^{-+}	2^{+-}	2^{--}	2^{++}	2^{--}	2^{+-}
	$\pi_2(1670)$ $\eta_2(1645)$ $K_2(1770)$	$f_2(1565)$	$\eta_2(1870)$		$K_2(1820)$	$a_2(1700)$ $f_2(1640)$ $f_2(1810)$		
					1^3D_3			
					3^{--}	3^{++}	3^{--}	3^{+-}
					$\rho_3(1690)$ $\omega_3(1670)$ $\phi_3(1850)$ $K_3^*(1780)$		$\rho_3(1990)$	

IV. Concluding remarks

(1) We present the possible assignments for all the observed mesons below ~ 1.8 GeV in the covariant level-classification scheme.

(2) We have to examine decay properties of the chiral and conventional states to establish their assignments.

(3) It is expected that there may exist many meson states to be observed below ~1.8 GeV, including the exotic mesons with $J^{PC} = 0^{+-}, 0^{--}, 1^{-+}, 2^{+-}$.

(4) It may be interesting to search for the 2^{++} mesons below 1.5 ~ 1.6 GeV, since the conventional tensor nonet is well established.