Quarkonium States of Light Mesons and Exotics

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Fig. 1

$(q_i \bar{q}_j)$, q_i = u, d, s $\quad {}^{2s+1}L_J$, $P = (-1)^{L+1}$, neutral: $C = (-1)^{L+S}$

gg, ggg - Glueball, $q\bar{q}g$ - Hybrid, $4q = q\bar{q}q\bar{q}$, M_1M_2 = meson molecule

Key:

n_i = u,d	I=1 $(n_i\bar{n}_j)$	I=0 $(n_i\bar{n}_i)$	I=0 $(s\bar{s})$	I=1/2 $\binom{n_i\bar{s}}{\bar{n}_i s}$
S=1, J=L+1				
S=1, J=L				
S=1, J=L-1				
S=0, J=L				

J^{PC} | name

mass (MeV)
domin. decays

2050 - Particle Data Group (1994)
2040 - Candidates
(1700) - Model predictions

EXOTICS

Peculiar properties (beyond $q\bar{q}$-scheme)

1. $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}$
2. Cryptoexotical states

J^+:

	$n_r=1$	$n_r=2$
${}^3F_4$	4^+ a_4 *2040* *3π, ρω* | 4^{++} f_4 2050 ωω, ππ | 4^{++} f_4' *2220* $K\bar{K}$ | 4^+ K_4^* 2045 $K\pi, K^*\pi$	
${}^3F_3$	3^+ a_3 *2050* $\pi f_2, \pi b_1$ | 3^{++} f_3 (2050) $\omega\omega, \pi^0 a_2^0$ | 3^{++} f_3' (2240) $K\bar{K}, K_2^*K$ | 3^+ K_{3A} *2320* $K\pi\pi$	
${}^3F_2$	2^+ a_2 (2050) $\pi f_2, \pi b_1$ | 2^{++} f_2 (2050) $\omega\omega, \pi^0 a_2^0$ | 2^{++} f_2' (2240) $K\bar{K}, K_2^*K$ | 2^+ K_2^* *2100* $K\pi$	
${}^1F_3$	3^+ b_3 (2030) $\pi\omega, \pi a_2$ | 3^{+-} h_3 (2030) $\pi^0\rho^0, \eta\omega$ | 3^{+-} h_3' (2220) $K\bar{K}\pi, K_2^*K$ | 3^+ K_{3B} (2120) $K\pi\pi, K_2^*\pi$	

J^-:

	$n_r=1$	$n_r=2$	$n_r=3$
${}^3D_3$	3^- ρ_3 1690 $4\pi, 2\pi$ | 3^{--} ω_3 1670 $3\pi, 5\pi$ | 3^{--} ϕ_3 1850 $K\bar{K}$ | 3^- K_3^* 1780 $K\rho, K^*\pi$		
${}^3D_2$	2^- ρ_2 (1700) $\pi\omega, \pi a_2$ | 2^{--} ω_2 (1700) $\pi^0\rho^0, \eta\omega$ | 2^{--} ϕ_2 (1910) $K^*\bar{K}, K_2^*K$ | 2^- $K_{2\rho}$ 1770 $K^*\pi, K_2^*\pi$	3^- ρ_3	
${}^3D_1$	1^- ρ_1 (1700) $\pi\omega, \pi a_2$ | 1^{--} ω_1 *1600* $\pi^0\rho^0, \pi^0 b_1^0$ | 1^{--} ϕ_1 (1880) $K\bar{K}, K^*\bar{K}$ | 1^- K_1^* 1680 $K\pi, K^*\pi$	2^- ρ_2	2^{++} X/f_2 1920 ωω (17) (qq̄)' | 2^{++} G/f_2 2180 ηη (18) (gg) | 2^{++} g/f_2 2010 φφ (19) (gg,M₁,M₂) | 2^{++} g/f_2 2300 φφ (20) (gg,M₁,M₂) | 2^{++} g/f_2 2340 φφ (21) (gg,M₁,M₂)
		1^- ρ_1 2200 $\omega\pi$	2^{++} AX/f_2 1515 ππ (14) (4q) | 2^{++} X/f_2 1640 ωω (15) (?) | 2^{++} f_2 1810 4π (16) (gg)
		2^- π_2	
${}^1D_2$	2^- π_2 1670 $\pi f_2, \pi\rho$ | 2^{-+} η_2 (1680) $\pi a_2, \omega\omega$ | 2^{-+} η_2' *1860* $K^*\bar{K}, K_2^*\bar{K}$ | 2^- $K_{2\pi}$ *1730* $K\rho, K_2^*\pi$		

J^+:

	$n_r=1$	$n_r=2$
${}^3P_2$	2^+ a_2 1320 $\pi\rho$ | 2^{++} f_2 1270 $\pi^0\pi^0$ | 2^{++} f_2' 1525 $K\bar{K}, \eta\eta$ | 2^+ K_2^* 1430 $K^*\pi$	a_2 | 2^{++} f_2 | 2^{++} f_2' | 2^+ K_2^* *1978*
${}^3P_1$	1^+ a_1 1260 $\pi\rho$ | 1^{++} f_1 1285 $\pi^0 a_0(980)$ | 1^{++} D/f_1' 1530 $K\bar{K}\pi$ | 1^+ K_{1A} 1400 $K\bar{K}\pi$	1^+ a_1 | 1^{++} f_1 1510 $\bar{K}K^*$ | 1^{++} f_1' | 1^+ K_{1A}
${}^3P_0$	0^+ a_0 1320 $\eta\pi$ | 0^{++} f_0 1300 $\pi^0\pi^0$ | 0^{++} f_0' 1520 $K\bar{K}$ | 0^+ K_0^* 1430 $K\pi$	0^+ | 1^{--} C 1480 $\phi\pi$ (4) (4q,qq̄g) | 0^{-+} i/η 1440 $K\bar{K}\pi$ (1) (gg) | 0^+ K_0^* *1950*
${}^1P_1$	1^+ b_1 1235 $\pi\omega$ | 1^{+-} h_1 1170 $\pi^0\rho^0$ | 1^{+-} h_1' 1380 $K\bar{K}\pi$ | 1^+ K_{1B} 1270 $K\pi\pi$	1^+ | K_{1B}

S_0:

	$n_r=1$			$n_r=3$
${}^3S_1$	1^- ρ 770 ππ | 1^{--} ω 783 πππ | 1^{--} φ 1020 KK̄ | 1^- K^* 892 Kπ	1^- ρ *1300* ππ | 1^{--} ω 1390 πρ | 1^{--} φ 1680 $K^*K, \pi\pi\omega$ | 1^- K^* 1410 πK^*_{890}	1^- ρ 1450,1700 4π, ππ | 1^{--} ω 1420,1600 πρ,ππω | 1^{--} φ | 1^- K^*
${}^1S_0$	0^- π 137 — | 0^{-+} η 549 — | 0^{-+} η' 958 ππη, ργ | 0^- K 494 —	0^- π 1300 3π | 0^{-+} η 1295 ππη, $\pi^0 a_2^0$ | 0^{-+} η' 1400 ππ, KK̄ | 0^- K *1460* (2) KK̄π	0^- π *1804* | 0^{-+} η | 0^{-+} η' | 0^- K

1^{++} E/f_1 1420 (13) $a_0\pi$, KK* (qq̄g)

0^{++} δ/a_0 980 (6) ηπ, KK (4q, M_1, M_2) | 0^{++} s^*/f_0 975 (7) ππ, KK (4q, M_1, M_2) | 0^{++} G/f_0 1590 (8) η'η, ηη (qq̄g,gg)

$1^+/2^-$ A_1/π_2 1814 (12) πηη, πηη' (gg,qq̄g)

1^{-+} M 1405 (3) ηπ (qq̄g) | 1^{-+} $\tilde{\rho}$ 1600 (5) ρπ, ηπ (qq̄g)

$0^+/2^+$ X 1910 (11) ηη' (M₁,M₂)

$0^+/2^+$ X/f_2 1740 (10) ηη (?)

$0^+/2^+$ θ/f_2 1720 (9) KK̄, ηη, ππ (gg)

2^{+-} Exotics $\quad \tilde{a}_2(1900) \to \pi a_2, \pi a_1, \quad \tilde{f}_2(1900) \to \pi^0 b_1^0, \eta\omega, \quad \tilde{f}_2(2100) \to \bar{K}K_1, \bar{K}K_2^*$

1^{-+} Exotics $\quad \tilde{\rho}_1(1900) \to \pi b_1, \pi f_1, \quad \tilde{\omega}_1(1900) \to \pi^0 a_1^0, \pi^0\pi^0_{1300}, \quad \tilde{\phi}_1(2100) \to \bar{K}K_1, \bar{K}K_2^*$

3^{-+} Exotics $\quad \tilde{\rho}_3(1900) \to \pi b_1, \pi f_1, \quad \tilde{\omega}_3(1900) \to \pi^0 a_1^0, \pi^0\pi^0_{1300}, \quad \tilde{\phi}_3(2100) \to \bar{K}K_1, \bar{K}K_2^*$

6^{+-} Exotics

$n_r=1$			
${}^3H_6$	6^+ a_6 *2450*	6^{++} f_6 *2510*	6^{++} f_6'	6^+ K_6^*
${}^3H_5$	5^+ a_5	5^{++} f_5	5^{++} f_5'	5^+ K_{5A}
${}^3H_4$	4^+ a_4	4^{++} f_4 *2030*	4^{++} f_4'	4^+ K_4^*
${}^1H_5$	5^+ b_5	5^{+-} h_5	5^{+-} h_5'	5^+ K_{5B}

J^+:

5^{-+} Exotics

$n_r=1$				
${}^3G_5$	5^- ρ_5	5^{--} ω_5	5^{--} ϕ_5	5^- K_5^* *2380*
${}^3G_4$	4^- ρ_4	4^{--} ω_4	4^{--} ϕ_4	4^- $K_{4\rho}$ *2500*
${}^3G_3$	3^- ρ 1690 $4\pi, \pi\pi$	3^{--} ω 1670 πρ, πππ	3^{--} ϕ_3	3^- K_3^*
${}^1G_4$	4^- π_4	4^{-+} η_4	4^{-+} η_4'	4^- $K_{4\pi}$

J^-:

4^{+-} Exotics $\quad \tilde{a}_4(1900) \to \pi a_2, \eta b_1, \quad \tilde{f}_4(1900) \to \pi^0 b_1^0, \quad \tilde{f}_4'(2100) \to \bar{K}K_1, \bar{K}K_2^*$

$n_r=1$				
${}^3F_4$	4^+ a_4 *2040* *3π, ρω*	4^{++} f_4 2050 ωω, ππ	4^{++} f_4' *2220* $K\bar{K}$	4^+ K_4^* 2045 $K\pi, K^*\pi$
${}^3F_3$	3^+ a_3 *2050* $\pi f_2, \pi b_1$	3^{++} f_3 (2050) $\omega\omega, \pi^0 a_2^0$	3^{++} f_3' (2240) $K\bar{K}, K_2^*K$	3^+ K_{3A} *2320* $K\pi\pi$
${}^3F_2$	2^+ a_2 (2050) $\pi f_2, \pi b_1$	2^{++} f_2 (2050) $\omega\omega, \pi^0 a_2^0$	2^{++} f_2' (2240) $K\bar{K}, K_2^*K$	2^+ K_2^* *2100* $K\pi$
${}^1F_3$	3^+ b_3 (2030) $\pi\omega, \pi a_2$	3^{+-} h_3 (2030) $\pi^0\rho^0, \eta\omega$	3^{+-} h_3' (2220) $K\bar{K}\pi, K_2^*K$	3^+ K_{3B} (2120) $K\pi\pi, K_2^*\pi$

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${}^3G_3$	3^- ρ 1690 $4\pi, \pi\pi$	3^{--} ω 1670 πρ, πππ	3^{--} ϕ_3	3^- K_3^*
${}^1G_4$	4^- π_4	4^{-+} η_4	4^{-+} η_4'	4^- $K_{4\pi}$

J^-:

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${}^3H_5$	5^+ a_5	5^{++} f_5	5^{++} f_5'	5^+ K_{5A}
${}^3H_4$	4^+ a_4	4^{++} f_4 *2030*	4^{++} f_4'	4^+ K_4^*
${}^1H_5$	5^+ b_5	5^{+-} h_5	5^{+-} h_5'	5^+ K_{5B}

J^+:

$\tilde{\omega}_3(1900) \to \pi^0 a_1^0, \pi^0\pi^0_{1300}, \quad \tilde{\phi}_3(2100) \to \bar{K}K_1, \bar{K}K_2^*$

$\tilde{\rho}_1(1900) \to \pi b_1, \pi f_1, \quad \tilde{\omega}_1(1900) \to \pi^0 a_1^0, \pi^0\pi^0_{1300}, \quad \tilde{\phi}_1(2100) \to \bar{K}K_1, \bar{K}K_2^*$

$\tilde{\pi}_0(1900) \to \pi\omega_1, \pi\rho_1, \quad \tilde{\eta}_0(1900) \to \eta\omega, \quad \tilde{\eta}_0'(2100) \to \bar{K}K^*$

$\tilde{a}_0(1900) \to \pi\pi_{1300}, \quad \tilde{f}_0(1900) \to \pi^0 b_1^0, \quad \tilde{f}_0'(2100) \to \bar{K}K_1$

L: 5 4 3 2 1 0

0 1 2 3 4 5

$M^2(q\bar{q})$, GeV/c^2