The predictions for the masses, widths and branching ratios of four quark states with $I^G(J^{PC}) = 0^-(1^{+-})$, $0^+(1^{++})$ and $1^-(1^{++})$

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Applying the Diquark Cluster Model(DCM) to explain the various problems concerning the exotic meson, we already have obtained many fruitful results [1].

Most of the recent experimental evidence with respect to the exotic meson appear to support the DCM as useful here as it has been in the case of the dibaryon [2].

Detail description of the DCM is in ref.1 including the decay processes. The results of calculation for the f_1, h_1 and a_1 families are tabulated in the table 1,2 and 3,respectively.

State	Conf.	TS	Γ (MeV) case(1)/case(2)	major decay mode (%)
${B^0}_{F_1}(1510)$	$[(1p_{1/2})(1s_{1/2})]^2$	[01][00]	162/160	$(\rho)\rho/96.5$ $(f_0)\eta/2.1$ $(a_0)\pi/0.6$ $(\omega)\omega/0.5$
${B^0}_{F_1}(1615)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[00][01]	15.6/8.74	$(a_1)\pi/43.0$ $(f_0)\eta/34.5$ $(a_0)\pi/12.0$ $(\rho)b_1/4.4$
${B^0}_{F_1}(1950)$	$[(1d_{3/2})(1s_{1/2})]^2$	[01][02]	40.1/29.8	$(\rho^*)\rho/15.1$ $(\rho)b_1/12.2$ $(f_0)\eta/12.2$ $(b_1)\rho/10.7$
${B^0}_{f_1}(1440)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][10]	10.5/5.36	$(f_0)\eta/96.5$ $(a_0)\pi/2.8$ $(h_1)\omega/0.3$ $(\rho^*)\rho/0.2$
${B^0}_{f_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[11][11]	212/207	$(\omega)\omega/55.3$ $(\rho)\rho/37.0$ $(f_0)\eta/3.5$ $(h_1)\omega/2.4$
${B^0}_{f_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[11][12]	89.3/65.0	$(f_0)\eta/42.1$ $(\omega)\omega/26.3$ $(\rho)\rho/17.6$ $(a_1)\pi/8.8$
${B^0}_{f_1}(1950)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][12]	408/385	$(\omega)\omega/54.7$ $(\rho)\rho/16.8$ $(h_1)\omega/14.1$ $(f_0)\eta/3.6$

Table 1. Predictions for the four quarks with $I^G(J^{PC})$=$0^+(1^{++})$ f_1 family.

The first column B expresses the four quark state and the upper suffix 0 denotes a mesonic state while the lower suffix is the same spin and parity as the resonance state of a meson. In parentheses are the mass of resonance in MeV. The second column is a configuration of the four quark state using the diquark cluster mode. The third column lists the T-spin and spin combination of each configuration. The fourth column is the calculated decay width in MeV. The last column lists several decay modes and fractions of a state. In parentheses are the decay states and after this are expressions of real observable mesons. List is the decay fraction in %. The same notation are used in tables 2 and 3.

State	Conf.	TS	Γ (MeV) case(1)/case(2)	major decay mode (%)
$B^0{}_{H_1}(1510)$	$[(1p_{1/2})(1s_{1/2})]^2$	[01][00]	40.8/44.7	$(\rho)\pi/65.7$ $(\omega)\eta/12.6$ $(a_1)\rho/7.5$ $(\rho)a_1/5.4$
$B^0{}_{H_1}(1520)$	$[(1p_{1/2})(1s_{1/2})]^2$	[01][01]	38.8/32.2	$(\rho)\pi/46.5$ $(f_0)\omega/18.2$ $(\omega)\eta/12.6$ $(a_1)\rho/7.8$
$B^0{}_{H_1}(1615)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[00][01]	13.6/7.82	$(a_1)\rho/45.3$ $(\rho)a_1/21.8$ $(f_0)\omega/21.5$ $(a_0)\rho/7.3$
$B^0{}_{H_1}(1950)$	$[(1d_{3/2})(1s_{1/2})]^2$	[01][01]	7.04/3.99	$(\pi^*)\rho/24.8$ $(\rho^*)\pi/17.7$ $(\rho)\pi^*/12.5$ $(f_0)h_1/8.2$
	$[(1d_{3/2})(1s_{1/2})]^2$	[01][02]	60.8/33.3	$(a_1)\rho/54.6$ $(\rho)a_1/14.8$ $(\pi^*)\rho/8.4$ $(\rho)\pi^*/4.6$
	$[(1d_{3/2})(1s_{1/2})]^2$	[02][02]	111/67.4	$(a_1)\rho/48.1$ $(\rho)a_1/13.0$ $(f_0)\omega/11.4$ $(\rho)a_0/6.5$
$B^0{}_{h_1}(1670)$	$[(1s_{1/2})^2]^2$	[11][11]	22.1/22.1	$(\omega)\eta/54.1$ $(\rho)\pi/45.9$
$B^0{}_{h_1}(1440)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][10]	0.344/0.152	$(a_1)\rho/44.2$ $(\rho)a_1/38.5$ $(\pi^*)\rho/7.1$ $(\rho^*)\pi/6.1$
$B^0{}_{h_1}(1500)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][11]	25.4/13.5	$(f_0)\omega/83.1$ $(h_1)\eta/5.1$ $(f_0)h_1/5.0$ $(a_0)\rho/1.8$
$B^0{}_{h_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[11][11]	93.5/68.6	$(f_0)\omega/40.6$ $(\omega)\eta/36.8$ $(a_1)\rho/8.4$ $(\rho)\pi/5.7$
$B^0{}_{h_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})(1s_{1/2})]$	[11][12]	99.7/86.3	$(\omega)\eta/62.2$ $(f_0)\omega/21.2$ $(\rho)\pi/9.6$ $(a_1)\rho/3.3$
$B^0{}_{h_1}(1950)$	$[(1d_{3/2})(1s_{1/2})]^2$	[11][11]	289/245	$(\omega)\eta/50.7$ $(a_1)\rho/22.7(f_2)\omega/7.8$ $(h_1)\eta/5.4$
	$[(1d_{3/2})(1s_{1/2})]^2$	[11][12]	119/68.4	$(a_1)\rho/58.6$ $(\rho)a_1/13.7$ $(f_0)h_1/5.3$ $(h_1)\eta/5.2$
	$[(1d_{3/2})(1s_{1/2})]^2$	[12][12]	149/97.4	$(a_1)\rho/25.8$ $(f_0)\omega/25.6$ $(\omega)\eta/19.6$ $(\rho)a_1/5.9$

Table 2. Predictions for the four quark with $I^G(J^{PC})=0^-(1^{+-})$ h_1 family.

State	Conf.	TS	Γ (MeV) case(1)/case(2)	major decay mode (%)
$B^0{}_{A_1}(1475)$	$[(1s_{1/2})^2]^2$	[00][11]	27.7/27.7	$(\rho)\pi/56.0$ $(\rho)\omega/43.2$ $(\omega)\rho/0.8$
$B^0{}_{A_1}(1450)$	$[(1p_{1/2})(1s_{1/2})]^2$	[01][10]	2.86/1.74	$(a_1)\eta/35.4$ $(a_0)\rho/16.9$ $(a_1)\rho/15.6$ $(\rho)a_1/13.3$
$B^0{}_{A_1}(1500)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][00]	37.6/34.8	$(\rho)\omega/49.4$ $(\rho)\pi/30.5$ $(a_1)\eta/5.2$ $(a_1)\rho/4.3$
$B^0{}_{A_1}(1510)$	$[(1p_{1/2})(1s_{1/2})]^2$	[01][11]	34.6/31.0	$(\rho)\omega/42.1$ $(\rho)\pi/30.4$ $(f_0)a_1/6.7$ $(f_0)\pi/6.2$
$B^0{}_{A_1}(1615)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[00][11]	64.3/58.5	$(\rho)\omega/50.0$ $(\rho)\pi/23.3$ $(a_1)\rho/6.4$ $(a_1)\eta/5.1$
$B^0{}_{A_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[11][01]	30.1/20.0	$(a_1)\rho/52.1$ $(\rho)a_1/17.5$ $(\rho)a_0/8.6$ $(a_0)\rho/4.7$
$B^0{}_{A_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[11][02]	59.7/51.3	$(\rho)\omega/35.6$ $(\omega)\rho/15.3$ $(\rho)\pi/14.3$ $(a_1)\rho/11.1$
$B^0{}_{A_1}(1950)$	$[(1d_{3/2})(1s_{1/2})]^2$	[01][11]	113/67.1	$(a_1)\rho/57.9$ $(\rho)a_1/10.8$ $(h_1)\rho/4.3$ $(a_1)\eta/3.9$
	$[(1d_{3/2})(1s_{1/2})]^2$	[01][12]	77.2/46.7	$(a_1)\rho/44.5$ $(\rho)a_1/9.9$ $(\pi^*)\rho/4.4$ $(a_1)\eta/4.2$
	$[(1d_{3/2})(1s_{1/2})]^2$	[02][11]	202/152	$(a_1)\rho/34.2$ $(\rho)\omega/11.7$ $(\omega)\rho/10.3$ $(\rho)a_1/9.1$
	$[(1d_{3/2})(1s_{1/2})]^2$	[02][12]	144/105	$(a_1)\rho/26.3(\rho)\omega/16.3$ $(\omega)\rho/14.4$ $(f_0)a_1/11.9$
$B^0{}_{a_1}(1440)$	$[(1p_{1/2})(1s_{1/2})]^2$	[11][10]	5.37/3.09	$(f_0)\pi/40.2$ $(f_0)a_1/33.5$ $(a_0)\eta/20.8$ $(a_1)f_0/2.4$
$B^0{}_{a_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[11][11]	238/236	$(\rho)\omega/67.1$ $(\omega)\rho/28.8$ $(h_1)\rho/1.0$ $(f_0)\pi/0.7$
$B^0{}_{a_1}(1810)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[11][12]	64.8/55.8	$(\rho)\omega/49.3$ $(\omega)\rho/21.2$ $(f_0)\pi/12.7$ $(a_1)\eta/12.2$
$B^0{}_{a_1}(1950)$	$[(1s_{1/2})^2][(1d_{3/2})][(1s_{1/2})]$	[11][12]	358/346	$(\rho)\omega/39.4$ $(\omega)\rho/34.7$ $(h_1)\rho/7.7$ $(b_1)\omega/5.4$

Table 3. Predictions for the four quark with $I^G(J^{PC})=1^-(1^{++})$ a_1 family.

A comparison to the experimental data with the f_1 family is in figure 1, the h_1 family is in figure 2, respectively.

In sum, results from the experimental data and those from the DCM calculations are quite close. However, we need more precise information from further experimental data.

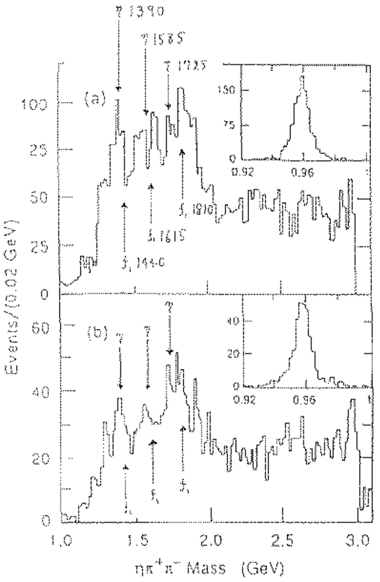

Figure 1

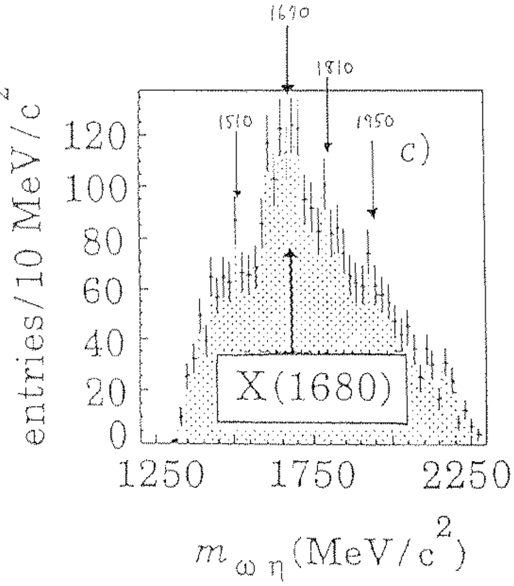

Figure 2

Figure 1. The $\eta\pi^+\pi^-$ invariant mass distribution in the decay $J/\psi \rightarrow \gamma\eta\pi^+\pi^-$ for the (a) $\eta \rightarrow \gamma\gamma$ and (b) $\eta \rightarrow \pi^+\pi^-\pi^0$ channel, and the predictions of the DCM (η and f_1 families). The data are taken from the MARK III Collaboration [3]. The arrows with the handwritten number indicate the masses (in MeV) of the four quark states with the $I^G(J^{PC})$ $=0^+(0^{-+})$(η family) [1] or $0^+(1^{++})$(f_1 family) with TS combination [1][1] which have appreciably large branching ratio to the $\eta\pi^+\pi^-$ channel.

Figure 2. The $\omega\eta$-invariant mass spectrum for the reaction $\bar{p}p \rightarrow \omega\eta\pi^0$ at a $\bar{p}$ momentum of 1940 MeV/c, and the predictions of the DCM (h_1 family). The data are from the Crystal Barrel Collaboration [4]. The arrows with the handwritten number indicate the mass of the four quark states with the $I^G(J^{PC})$=$0^-(1^{+-})$ which have appreciably large branching ratio to the $(\omega)\eta$ channel. Note that, through (ω) is not a real ω-meson, an appreciable decay to the $\omega\eta$ channel can occur through the direct fission mechanism of the self-energy type. Are the small structures the statistical fluctuations ? To get the answer to this question, further detailed analysis is desirable.

We also compare the results of the Oakden-Pennington [5] with ours in table 4 and 5. A more detailed report of the calculations will be publised in the future.

Configuration	M(GeV)	I	G	J	P
$[(1p_{3/2})(1s_{1/2})][(1d_{3/2})(1s_{1/2})]$	2.03	0,1,2	±1	0,1,2,3,4	-1
$[(1p_{3/2})(1s_{1/2})]^2$	2.07	0,1,2	±1	0,1,2,3,4	+1

Table 4. Predictions for the mass M, isospin I, G-parity, spin S and parity P of the $\bar{B}^0$ with the configuration of the DCM. The states with $I^G(J^{PC})$=$0^-(0^{+-})$, $0^-(4^{+-})$, $2^-(0^{+-})$ and $2^-(4^{+-})$ are excluded.

Exp.			Th.
I	J^{PC}	M(X_J)	M($\bar{B}^0$)
0	0^{++}	2.05	2.07
1	1^{--}	2.07	2.03
0	2^{++}	2.09	2.07
1	3^{--}	2.09	2.03
0	4^{++}	2.04	2.07

Table 5. Predictions for the DCM for the masses of $\bar{B}^0$ with the Oakden-Pennington solution A.

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