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PHYSICS LETTERS B

Physics Letters B 568 (2003) 254–260

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Testing the nature of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ states using radiative transitions

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Received 9 June 2003; accepted 26 June 2003

Editor: H. Georgi

Abstract

The Babar and CLEO Collaborations have recently observed states decaying to $D_s^+\pi^0$ and $D_s^{*+}\pi^0$, respectively, and suggest the possible explanation that they are the missing P-wave $c\bar{s}$ states with $J^P = 0^+$ and 1^+. In this Letter we compare the properties of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ states to those expected of the $c\bar{s}$ D_{s0}^* and D_{s1} states. We expect the D_{s0}^* and D_{s1} with the reported masses to be extremely narrow, $\Gamma \sim \mathcal{O}(10\text{ keV})$, with large branching ratios to $D_s^*\gamma$ for the D_{s0}^* and to $D_s^*\gamma$ and $D_s\gamma$ for the D_{s1}. Crucial to this interpretation of the Babar and CLEO observations is the measurement of the radiative transitions. We note that it may be possible to observe the $D_{s1}(2536)$ in radiative transitions to the D_s^*.

PACS: 12.39.-x; 13.20.Fc; 13.25.Ft; 14.40.Lb

1. Introduction

Over the last decade there has been considerable progress in our understanding of mesons, strongly interacting bound states of quarks and antiquarks. Mesons made of one heavy and one light quark have played an important role [1]. However, the theoretical predictions have not been sufficiently tested by experimental data to say that we truly understand the strong interaction. This situation has recently been highlighted by the discovery of a state, the $D_{sJ}^*(2317)^+$, with mass 2317 MeV decaying to $D_s^+\pi^0$ by the Babar Collaboration at the Stanford Linear Accelerator Center (SLAC) [2] and a second state, the $D_{sJ}(2463)^+$, with mass 2.463 GeV decaying to $D_s^{*+}\pi^0$ by the CLEO Collaboration at the Cornell Electron Storage Ring [3]. These states have also been observed by the Belle Collaboration at KEK [4]. The $D_{sJ}^*(2317)^+$ was observed in the inclusive $D_s^+\pi^0$ invariant mass distribution [2]. The state has natural spin-parity and the Babar Collaboration suggests it to be a $J^P = 0^+$ state based on its low mass. The quantum numbers of the final state indicate that the decay violates isospin conservation. Babar found no evidence for the decay $D_{sJ}^*(2317)^+ \to D_s^{*+}\gamma$ or $D_s^+\gamma\gamma$ and although they found no evidence for the decay $D_{sJ}^*(2317)^+ \to D_s^+\gamma$ they see a peak near 2.46 GeV in the $D_s^+\pi^0\gamma$ mass dis-

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doi:10.1016/j.physletb.2003.06.049

tribution but do not claim this as evidence for a new state.

The CLEO Collaboration subsequently reported on a signal in the $D_s^{*+}\pi^0$ channel at a mass of 2.463 GeV which they refer to as the $D_{sJ}(2463)^+$ [3]. Because the $D_{sJ}(2463)$ lies above the kinematic threshold to decay to DK but not D^*K the narrow width suggests the decay to DK does not occur. Since angular momentum and parity conservation forbids a 1^+ state from decaying to two pseudoscalars, CLEO suggests the compatability of the $D_{sJ}(2463)$ with the $J^P = 1^+$ hypothesis. CLEO puts limits on the widths of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ of $\Gamma < 7$ MeV at 90% C.L. [3]. More importantly for the purpose of this analysis, they give limits on radiative transitions of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ to $D_s^{*+}\gamma$ and $D_s^+\gamma$ final states.

The simplest interpretation is to identify these states as the missing $j = 1/2$ members of the $c\bar{s}$ $L = 1$ multiplet where $j = 1/2$ is the angular momentum of the s-quark. The observation of these states is surprising because they are narrower than expected, are observed in isospin violating $D_s\pi^0$ and $D_s^*\pi^0$ final states, and are lower in mass than expected by most (but not all) calculations [5–14]. The Babar and CLEO observations have led to conflicting interpretations. Although the observed mass for the D_{s0} candidate (the $J^P = 0^+$ member of the ground state $L = 1$ $c\bar{s}$ multiplet) is consistent with some predictions of chiral quark models [14,15] in which broken chiral symmetry views them as the positive-parity partners of the D_s and D_s^* states, it is considerably lower than expected by most quark models [5,6,8,9,11] and lattice QCD calculations [12,13]. This has led to considerable interest [16–19] including the proposal that the $D_J(2317)^+$ is a multiquark state [20,21], possibly a DK molecule analogous to the $K\overline{K}$ interpretation of the $f_0(980)$ and $a_0(980)$.

In this Letter we confront the $c\bar{s}$ $L = 1$ D_{s0}^* and D_{s1} interpretations of these states with the theoretical expectations for conventional $c\bar{s}$ states.

2. Spectroscopy

Mass predictions are an important test of QCD motivated potential models as well as other calculational approaches for hadron spectroscopy [5–13, 15]. In QCD-motivated potential models the spin-dependent splittings test the Lorentz nature of the confining potential with different combinations of Lorentz scalar, vector, etc. interactions [5–11]. Furthermore, the observation of heavy-light mesons is an important validation of heavy quark effective theory [22,23] and lattice QCD calculations [12,13]. In Table 1 we summarize predictions for the P-wave $c\bar{s}$ states. The two $J = 1$ states are linear combinations of ${}^3P_1$ and ${}^1P_1$ because for unequal mass quarks, C is no longer a good quantum number. We label these as the D_1^h and D_1^l. Most, but not all, models predict the masses of the D_{s0}^* and the missing D_1 state to be substantially higher than the masses reported by Babar [2] and CLEO [3]. Although it is possible that these models need revision it seems unlikely that they would disagree with experiment to such a large degree given their general success in describing the meson spectrum. A more serious problem is the large discrepancy with lattice QCD calculations which give $M(D_{s0}^*) = 2499(13)(5)$ MeV and $M(D_{s1}) = 2500(16)(2)$ MeV [12]. If the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ are identified as the missing ${}^3P_0(c\bar{s})$ and $P_1(c\bar{s})$ states it would pose a serious challenge for the lattice calculations.

Quark model calculations [6] and heavy quark symmetry [22] predict that the 4 $L = 1$ $c\bar{s}$ mesons are grouped into two doublets with properties characterized by the angular momentum of the lightest quark, $j = 1/2$ and $j = 3/2$. The $j = 3/2$ states are identified with the previously observed $D_{s1}(2536)^{\pm}$ and

Table 1
Predictions for the P-wave $c\bar{s}$ states. The $J = 1$ states are linear combinations of the ${}^3P_1$ and ${}^1P_1$ states. In column 3 we list D_1^h which we take to be the higher mass state of the two $J = 1$ physical states and D_1^l the lower. PDG refers to the particle data group [24] and LGT refers to the lattice gauge theory result

Reference	${}^3P_0$	D_1^h	D_1^l	${}^3P_2$
Babar [2]	2.32			
CLEO [3]			2.463	
PDG [24]		2.535		2.574
GI [5,6]	2.48	2.56	2.55	2.59
ZVR [7]	2.38	2.52	2.51	2.58
EGF [8]	2.508	2.569	2.515	2.560
DE [9]	2.487	2.605	2.535	2.581
GJ [10]	2.388	2.536	2.521	2.573
LNR [11]	2.455	2.522	2.502	2.586
LW [LGT] [12]	2.499	2.511	2.500	2.554
GB [LGT] [13]	2.437			

$D_{sJ}(2573)^{\pm}$ states [24] while the $j = 1/2$ have not previously been observed. The $j = 3/2$ states are predicted to be relatively narrow [6], in agreement with experiment [24]. In contrast, assuming the higher masses predicted by the quark model, the $j = 1/2$ states are expected to be rather broad, decaying to DK and D^*K, respectively, with large S-wave widths. The large width is presumed to explain why they have yet to be observed. However, if these states are identified with the recently observed $D_{sJ}^*(2317)$ and $D_{sJ}(2463)$ states their masses would be below the DK and D^*K thresholds so that they would be quite narrow, especially for mesons with such high mass.

3. Radiative transitions

While masses are one test of models of hadrons, transitions probe the internal structure of the state. Comparison between theory and experiment of the branching ratios is an important test of any assignment for a state. The Babar Collaboration observed the $D_{sJ}^*(2317)^+$ in the $D_s\pi^0$ final state and report no observation of its decay via radiative transitions [2]. The CLEO Collaboration put limits on branching ratios of various radiative decays of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)^+$ relative to $\Gamma(D_{sJ}^*(2317)^+ \to D_s^+\pi^0)$ and $\Gamma(D_{sJ}(2463)^+ \to D_s^{*+}\pi^0)$, respectively [3]. Because the $D_{sJ}^*(2317)^+$'s mass is below the kinematic threshold for the decay $D_{s0} \to DK$, the only kinematically allowed strong decay is $D_{s0} \to D_s\pi^0$. Likewise, the $D_{sJ}(2463)$ is kinematically forbidden to decay to its expected dominant decay mode $D_{s1} \to D^*K$ so that the $D_{s1} \to D_s^*\pi^0$ is expected to be dominant. In both cases the decays $D_{s0}^* \to D_s\pi^0$ and $D_{s1} \to D_s^*\pi^0$ violate isospin and are expected to have quite small partial widths. Thus, the radiative transitions $D_{s0}^* \to D_s^*\gamma$, $D_{s1} \to D_s^*\gamma$ and $D_{s1} \to D_s\gamma$ would be expected to have prominent branching ratios.

The E1 radiative transitions are given by

$$\Gamma(i \to f + \gamma) = \frac{4}{27}\alpha\langle e_Q\rangle^2\omega^3(2J_f + 1) \times \left|\left\langle {}^{2s+1}S_{J'}\right|r\left|{}^{2s+1}P_J\right\rangle\right|^2 \mathcal{S}_{if}, \tag{1}$$

where $\mathcal{S}_{if}$ is a statistical factor with $\mathcal{S}_{if} = 1$ for the transitions between spin-triplet states, $D_{sJ}^{(*)}(1P) \to D_s^*\gamma$ and $D_s^*(2S) \to D_{sJ}(1P)\gamma$, and $\mathcal{S}_{if} = 3$ for the transition between spin-singlet states, $D_{s1} \to D_s\gamma$, $\langle e_Q\rangle$ is an effective quark charge given by

$$\langle e_Q\rangle = \frac{m_s e_c - m_c e_{\bar{s}}}{m_c + m_s}, \tag{2}$$

where $e_c = 2/3$ and $e_{\bar{s}} = 1/3$ are the charges of the c-quark and s-antiquark given in units of $|e|$, $m_c = 1.628$ GeV, $m_s = 0.419$ GeV are the mass of the c and s quarks taken from Ref. [5], $\alpha = 1/137.036$ is the fine-structure constant, and ω is the photon's energy. The matrix elements $\langle S|r|P\rangle$, given in Table 2, were evaluated using the wavefunctions of Ref. [5]. Relativistic corrections are included in the E1 transition via Siegert's theorem [25–27] by including spin dependent interactions in the Hamiltonian used to calculate the meson masses and wavefunctions. To calculate the appropriate photon energies the PDG [24] values were used for observed mesons while the predictions from Ref. [5] were used for unobserved states with the following modification. While splittings between $c\bar{s}$ states predicted by Ref. [5] are in good agreement with experiment the masses are slightly higher than observed so to give a more reliable estimate of phase space, the masses used in Table 2 have been adjusted lower by 18 MeV from the predictions of Ref. [5]. For the D_{s0}^* and D_{s1} states we give one set of predictions using the Babar and CLEO masses and a second set of predictions using the quark model mass predictions of Ref. [5].

A final subtlety is that the $J = 1$ states are linear combinations of ${}^3P_1$ and ${}^1P_1$ because for unequal mass quarks, C is no longer a good quantum number. Thus,

$$D_{s1}^{3/2} = {}^1P_1\cos\theta + {}^3P_1\sin\theta,$$
$$D_{s1}^{1/2} = -{}^1P_1\sin\theta + {}^3P_1\cos\theta, \tag{3}$$

we use $\theta = -38°$ and the conventions of Ref. [6] in calculating the widths in Table 2 which include the appropriate factors of $\cos^2\theta$ and $\sin^2\theta$ as appropriate. The resulting widths are given in Table 2.

In addition to the E1 transitions the M1 transitions $D_{s1} \to D_{s0}^*\gamma$ can also take place. However, we found these partial widths to be quite small and unlikely to be observable.

Table 2

Predictions for partial widths and branching ratios for E1 transitions $2S \to 1P$ and $1P \to 2S$ and strong decays in the D_s meson sector. For the D_{s0}^* and $D_{s1}^{1/2}$ states we show results for two sets of assumptions. In the first we associate the newly observed $D_{sJ}^*(2.317)$ and $D_{sJ}(2.463)$ with the D_{s0}^* and $D_{s1}^{1/2}$ while in the second we show partial widths using the quark model predictions for these states's masses. For decays involving the D_{s1} states we include the appropriate $\cos^2\theta$ and $\sin^2\theta$ factors corresponding to Eq. (3) in the partial widths. The widths are given in keV unless otherwise noted. The masses come from the PDG [24] unless otherwise noted

Initial state	Final state	M_i (GeV)	M_f (GeV)	k (MeV)	$\langle 1P\|r\|nS\rangle$ (GeV^{-1})	Width (keV)	BR
$D_{s0}^*(2317)^+$	$D_s^*\gamma$	2.317[a]	2.112	196	2.17[b]	1.9	∼16 %
	$D_s\pi^0$	2.317[a]	1.968	297		∼10	∼84%
$D_{s0}^*(2466)^+$	$D_s^*\gamma$	2.466[c]	2.112	329	2.17[b]	9.0	3×10^{-5}
	DK	2.466[c]		289		280 MeV[d]	∼100%
$D_{s1}^{1/2}(2.463)$	$D_s^*\gamma$	2.463[e]	2.112	326	2.18[b]	5.5	24%
	$D_s\pi^0$	2.463[e]	1.968	297		∼10	43%
	$D_s\pi\pi$	2.463[e]	1.968	297		∼1.6	7%
	$D_s\gamma$	2.463[e]	1.968	445	1.86[b]	6.2	27%
$D_{s1}^{1/2}(2.536)$	$D_s^*\gamma$	2.536[c]	2.112	388	2.18[b]	9.2	7×10^{-5}
	D^*K	2.536[c]		384		130 MeV[d]	∼100%
	$D_s\gamma$	2.536[c]	1.968	504	1.86[b]	9.0	7×10^{-5}
D_{s2}^*	$D_s^*\gamma$	2.574	2.112	420	2.17[b]	19	$\sim1.3\times10^{-3}$ [f]
$D_{s1}^{3/2}$	$D_s^*\gamma$	2.535	2.112	388	2.18[b]	5.6	1.6%
	D^*K	2.535		382		340[g]	97%
	$D_s\gamma$	2.535	1.968	503	1.86[b]	15	4.2%
$D^*(2S)$	$D_{s2}^*\gamma$	2.714[c]	2.574	136	2.60[b]	1.5	
	$D_{s1}^{3/2}\gamma$	2.714[c]	2.535	173	2.25[b]	0.5	
	$D_{s1}^{1/2}(2.536)\gamma$	2.714[c]	2.536[c]	172	2.25[b]	0.9	
	$D_{s1}^{1/2}(2.463)\gamma$	2.714[c]	2.463[e]	239	2.25[b]	2.3	
	$D_{s0}^*\gamma$	2.714[c]	2.466[c]	237	1.95[b]	0.9	
	$D_{s0}^*\gamma$	2.714[c]	2.317[a]	368	1.95[b]	3.4	

[a] From Babar Ref. [2].
[b] Obtained using the wavefunctions generated from Ref. [5].
[c] Masses taken from Ref. [5] with the modification that the predictions have been adjusted downward by 18 MeV to give better agreement with the measured masses. The masses in Ref. [5] were rounded to 10 MeV. Here we round to 1 MeV.
[d] Obtained by rescaling the result of Ref. [6] by phase space.
[e] From CLEO Ref. [3].
[f] Based on the PDG total width for the $D_{sJ}(2573)^{\pm}$ [24].
[g] The PDG gives $\Gamma < 2.3$ MeV 90% C.L. We used the width given by Ref. [6] rescaled for phase space.

4. Strong transitions

The transition $D_{s0}^* \to D_s\pi^0$ is expected to be quite small as it violates isospin. Although there are a number of theoretical predictions for hadronic transitions between quarkonium levels [29–33] we know of none for the transition $D_{s0}^* \to D_s\pi^0$. To estimate this partial width we turn to known transitions and use existing theoretical calculations for guidance. This approach should at least help us gauge the relative importance of this partial width. The only measured transition is $\psi(2S) \to J/\psi(1S) + \pi^0$ with $\mathcal{B} = 9.7 \times 10^{-4}$ [24] implying $\Gamma(\psi' \to J/\psi\pi^0) = 0.27$ keV. A limit exists on the transition $\Upsilon(2S) \to \Upsilon(1S) + \pi^0$

of $\mathcal{B}(\Upsilon(2S) \to \Upsilon(1S)\pi^0) < 1.1 \times 10^{-3}$ 90% C.L. implying $\Gamma(\Upsilon(2S) \to \Upsilon(1S)\pi^0) < 0.05$ keV [24]. The BR for the transition $D_s^* \to D_s + \pi^0$ is $5.8 \pm 2.5\%$ but the total width is not known. We can estimate the width by using the measured branching ratio $\mathcal{B}(D_s^* \to D_s\gamma) = (94.2 \pm 2.5)\%$ with a quark model calculation of the radiative transition $D_s^* \to D_s\gamma$. Combining the partial width given by Ref. [5] of $\Gamma(D_s^* \to D_s\gamma) = 0.125$ keV with the measured branching ratio [24] gives $\Gamma(D_s^* \to D_s\pi^0) \simeq 7.7$ eV. For comparison Goity and Roberts [28] obtain $\Gamma(D_s^* \to D_s\gamma) = 0.165$ keV giving $\Gamma(D_s^* \to D_s\pi^0) = 10$ eV (for the $\kappa = 0.45$ solution) and Ebert et al. [8] find $\Gamma(D_s^* \to D_s\gamma) = 0.19$ keV giving $\Gamma(D_s^* \to D_s\pi^0) = 12$ eV.

For our first attempt to estimate $\Gamma(D_{s0}^* \to D_s\pi^0)$ we rescale $\Gamma(D_s^* \to D_s\pi^0)$ assuming a k_π^3 dependence for the partial widths and find $\Gamma(D_{s0}^* \to D_s\pi^0) \simeq 2$ keV. One should take this estimate with a grain of salt as the $D_s^* \to D_s\pi^0$ is an $S \to S$ transition with the final states in a relative P-wave while the $D_{s0}^* \to D_s\pi^0$ transition is a $P \to S$ transition with the final states in a relative S-wave so there are wavefunction effects we have totally ignored in addition to a generally cavalier attitude to kinematic factors. All we have attempted to do is establish the order of magnitude.

A more relevant starting point is the transition $h_c(^1P_1) \to J/\psi\pi^0$ which is a $P \to S$ spin-flip transition which proceeds via the E1–M1 interference term in a multipole expansion of the gluonic fields, similar to the $^3P_0 \to {}^1S_0$ transition we are attempting to estimate. Ko estimates $\Gamma(h_c \to J/\psi\pi^0) \simeq 2.5$ keV [33]. This transition is related to the transition $\psi' \to h_c\pi^0$ [30,33] for which Ko [33] obtains $\mathcal{B}(\psi' \to h_c\pi^0) = 3 \times 10^{-3}$. For comparison Voloshin [30] finds $\mathcal{B}(\psi' \to h_c\pi^0) = 10^{-3}$ so that we should assume a factor of 3 in uncertainty. These transitions are proportional to the pion momentum so that by rescaling the estimate of $\Gamma(h_c \to J/\psi\pi^0)$ we find $\Gamma(D_{s0}^* \to D_s\pi^0) \simeq 2$ keV. There are two important uncertainties in this estimate. The first is that the matrix elements are proportional to $\langle S|r|P\rangle$. Using the wavefunctions of Ref. [5] we find $\langle 1^3P_0|r|1^1S_0\rangle_{cs}/\langle 1^3S_1|r|1^1P_1\rangle_{cc} = 1.1$. The second uncertainty is that the matrix elements are $\mathcal{O}(\alpha_s)$ so that the ratio of the widths go like $(\alpha_s(c\bar{s}))/\alpha_s(c\bar{c}))^2$ which, given that the relevant energy scale is the light quark mass, could contribute an additional factor of 4 in the width. Given these uncertainties we estimate that $\Gamma(D_{s0}^*(2.32) \to D_s\pi^0) \sim 10$ keV. We expect similar rates for the decays $D_{s1} \to D_s^*\pi^0$ (see Refs. [19] and [14]). In addition to the one-pion decay modes, the D_{s1} state can decay via two-pion transitions to the D_s state. (The decay $D_{s0}^* \to D_s\pi\pi$ is forbidden by parity conservation.) Using Ko's estimate of the ratio $\Gamma(h_c \to J/\psi + \pi\pi)/\Gamma(h_c \to J/\psi + \pi^0) \simeq 0.16$ [33] we estimate $\Gamma(D_{s1} \to D_s\pi\pi) \simeq 1.6$ keV. The resulting partial widths and branching ratios are summarized in Table 2.

For comparison we also include in Table 2 the partial widths and branching ratios expected for the $1^3P_0(c\bar{s})$ state with mass 2.466 MeV and the $D_{s1}^{1/2}$ state with mass 2.536 MeV. The dominant decays for these masses are $D_{s0}^* \to DK$ and $D_{s1}^{1/2} \to D^*K$ with large partial widths. Although there is considerable uncertainty in the estimate of these widths [6,34] we do expect the D_{s0}^* and $D_{s1}^{1/2}$ states with these masses to be rather broad with small branching ratios for the radiative transition. These decays are S-wave so the widths scales linearly with the decay products momentum.

For completeness we also include in Table 2 other E1 transitions involving the $c\bar{s}$ P-wave states. We note that the $D_{s1}(2536)^\pm$ should have a relatively large branching ratio for its radiative transition to $D_s^{*\pm}\gamma$ so that it may be possible to observe the $D_{s1}(2536)^\pm$ in this mode.

CLEO [3] has obtained 90% C.L. limits on radiative transitions of the $D_{sJ}^*(2317)$ and $D_{sJ}(2463)$ which we summarize along with our predictions in Table 3.

Table 3
Comparison of 90% C.L. limits on radiative transitions obtained by CLEO [3] with the predictions given in Table 2. The BR's are with respect to the decay $D_{s0}^*(2317) \to D_s\pi^0$ for the $D_{sJ}^*(2317)$ and with respect to the decay $D_{s1}^{1/2}(2463) \to D_s^*\pi^0$ for the $D_{sJ}(2463)$

Transition	Predicted	CLEO [3]
$D_{sJ}^*(2317) \to D_s^{*+}\gamma$	0.19	< 0.059
$D_{sJ}^*(2317) \to D_s^+\gamma$	0.0	< 0.052
$D_{sJ}(2463) \to D_s^{*+}\gamma$	0.55	< 0.16
$D_{sJ}(2463) \to D_s^+\gamma$	0.62	< 0.49
$D_{sJ}(2463) \to D_{sJ}^*(2317)\gamma$	1.2×10^{-3}	< 0.58

5. Other possibilities

If the radiative transitions are not observed with BR's consistent with those of the conventional D_{s0}^* and D_{s1} states what are the alternatives? One possibility suggested by the Babar Collaboration is that the $D_{sJ}^*(2317)^+$ is some sort of multiquark state, either a DK molecule or a $c\bar{q}q\bar{s}$ multiquark object. This seems to be a likely possibility which has much in common with the description of the $f_0(980)$ and $a_0(980)$ as multiquark states: The $D_{sJ}^*(2317)^+$ lies just below the DK threshold while the $f_0(980)/a_0(980)$ lie just below the $K\overline{K}$ threshold and both couple strongly to these nearby channels. This explanation has been promoted by Barnes, Close and Lipkin [20] and is supported by a recent dynamical calculation by van Beveren and Rupp [21]. Likewise, the $D_{sJ}(2463)$ could be a D^*K bound state similar to the $K^*\overline{K}$ molecule interpretation advocated as the solution to the longstanding E/ι puzzle [35].

6. Conclusions

The discovery of the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)$ has presented an interesting puzzle to meson spectroscopists. The Babar and CLEO Collaborations believe that they may be the missing $J^P = 0^+$ and 1^+ members of the $L = 1(c\bar{s})$ multiplet. However, their masses are significantly lower than expected by most models and also lattice QCD calculations and would pose a serious challenge to these calculations. It is therefore important to test these assignments. If the $D_{sJ}^*(2317)^+$ and $D_{sJ}(2463)$ are conventional D_{s0}^* and $D_{s1}^{1/2}$ $(c\bar{s})$ states we have argued that they should have very small total widths, $\mathcal{O}(10)$ keV, with large branching ratios to $D_s^*\gamma$ (and $D_s\gamma$ for the $D_{s1}^{1/2}$). It is therefore important to make a better determination of the total width of these states and to search for the radiative transitions. In contrast, the absence of the radiative transitions and a relatively large total width of $\mathcal{O}(\text{ MeV})$ would support the $D^{(*)}K$ molecule designations. In this case the conventional D_{s0}^* and $D_1^{1/2}$ states have yet to be discovered, presumably due to their large width. However, observation of their non-strange partners by the Belle Collaboration [36] with their expected properties leads us to be hopeful that they can be found.

Acknowledgements

The author thanks Ted Barnes and Sheldon Stone for useful comments and suggestions and Frank Close, Randy Lewis, and Jon Rosner for helpful communications. This research was supported in part by the Natural Sciences and Engineering Research Council of Canada.

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