

On the structure of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$

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We discuss the structure of the narrow mesons with charm and strangeness $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$, stressing the role of the radiative decay modes in shedding light on the quark content of these states. We argue that present experimental data favour the interpretation of the two states as ordinary $\bar{c}s$ mesons. We suggest the existence of resonances with similar properties and well predicted masses in the $\bar{b}s$ sector.

International Europhysics Conference on High Energy Physics
July 21st - 27th 2005
Lisboa, Portugal

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1. Introduction

The observation of two narrow resonances with charm and strangeness, $D_{sJ}^*(2317)$ in the $D_s\pi^0$ channel and $D_{sJ}(2460)$ in the $D_s^*\pi^0$ and $D_s\gamma$ channels [1], has raised discussions about the quark structure of these states [2]. Their identification with the scalar and axial vector $\bar{c}s$ mesons (D_{s0} and D'_{s1}) is natural; in the $m_c \rightarrow \infty$ limit such states are expected to be degenerate in mass and to form a $s_\ell^P = \frac{1}{2}^+$ doublet, with s_ℓ the angular momentum of the light degrees of freedom. In that interpretation $D_{sJ}^*(2317)$, $D_{sJ}(2460)$, $D_{s1}(2536)$ and $D_{s2}(2573)$ are the four lowest lying P-wave $\bar{c}s$ states. However, quark model estimates of the masses of these mesons generally produce larger values than the measured ones, implying that the two $\bar{c}s$ scalar and axial-vector D_{s0} and D'_{s1} states should be heavy enough to decay to DK and D^*K . Moreover, the $B \rightarrow D_{sJ}^*(2317)D$ and $B \rightarrow D_{sJ}(2460)D$ decay rates computed by naive factorization do not agree with experiment [3]. On this basis, other interpretations for $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ have been proposed, namely that of molecular states [4]. Radiative transitions probe the structure of hadrons and are suitable to understand the nature of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ since the rates can be predicted by various methods and compared to the experimental findings [5, 6]. One method is Light-Cone QCD sum rules [7].

2. Radiative decays by Light-Cone QCD Sum Rules

The $D_{sJ}^*(2317) \rightarrow D_s^*\gamma$ and $D_{sJ}(2460) \rightarrow D_s^{(*)}\gamma$, $D_{sJ}^*(2317)\gamma$ decay amplitudes:

$$\langle \gamma(q, \lambda) D_s^*(p, \lambda') | D_{s0}(p+q) \rangle = ed [(\varepsilon^* \cdot \tilde{\eta}^*)(p \cdot q) - (\varepsilon^* \cdot p)(\tilde{\eta}^* \cdot q)] \quad (2.1)$$

$$\langle \gamma(q, \lambda) D_s(p) | D'_{s1}(p+q, \lambda'') \rangle = eg_1 [(\varepsilon^* \cdot \eta)(p \cdot q) - (\varepsilon^* \cdot p)(\eta \cdot q)] \quad (2.2)$$

$$\langle \gamma(q, \lambda) D_s^*(p, \lambda') | D'_{s1}(p+q, \lambda'') \rangle = ie g_2 \varepsilon_{\alpha\beta\sigma\tau} \eta^\alpha \tilde{\eta}^{*\beta} \varepsilon^{*\sigma} q^\tau \quad (2.3)$$

$$\langle \gamma(q, \lambda) D_{s0}(p) | D'_{s1}(p+q, \lambda'') \rangle = ie g_3 \varepsilon_{\alpha\beta\sigma\tau} \varepsilon^{*\alpha} \eta^\beta p^\sigma q^\tau \quad (2.4)$$

($\varepsilon(\lambda)$ is the photon polarization vector and $\tilde{\eta}(\lambda')$, $\eta(\lambda'')$ the D_s^* and D'_{s1} polarization vectors) involve the hadronic parameters d, g_1, g_2 and g_3 . They can be determined by Light-Cone Sum rules [9, 10], starting from the light-cone expansion of correlation functions

$$F(p, q) = i \int d^4x e^{ip \cdot x} \langle \gamma(q, \lambda) | T [J_A^\dagger(x) J_B(0)] | 0 \rangle \quad (2.5)$$

of quark-antiquark currents $J_{A,B}$ having the same quantum number of the decaying and of the produced charmed mesons, and an external photon state of momentum q and helicity λ . In this expansion the perturbative photon coupling to the strange and charm quarks is considered together with the contributions of the photon emission from the soft s quark, expressed as photon matrix elements of increasing twist, fig.1 [11]. The correlation function can also be expressed in terms of the contribution of the lowest-lying resonances, the current-vacuum matrix elements of which are computed by the same method [12], and a continuum of states which is treated invoking global quark-hadron duality. A Borel transformation introduces an external parameter M^2 , the hadronic quantities being independent of it. The results depicted in fig. 2 correspond to the rates in Table 1.

The main result is that the rate of $D_{sJ}(2460) \rightarrow D_s\gamma$ is the largest one among the radiative $D_{sJ}(2460)$ rates, and this is confirmed by experiment, see Table 2. Since this result comes from

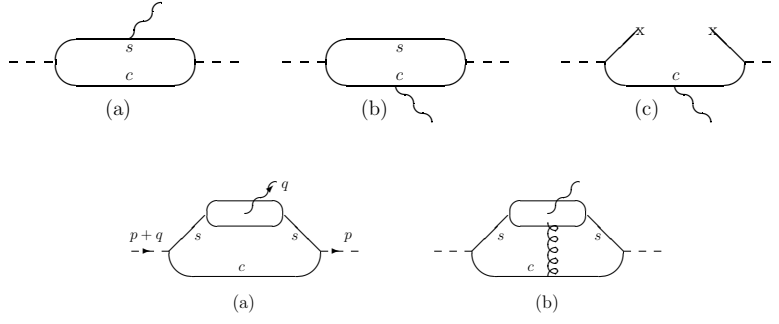


Figure 1: Diagrams describing the perturbative photon emission by the strange and charm quark ((a,b) in the first line) and two and three-particle photon distribution amplitudes (second line); (c) corresponds to the strange quark condensate contribution.

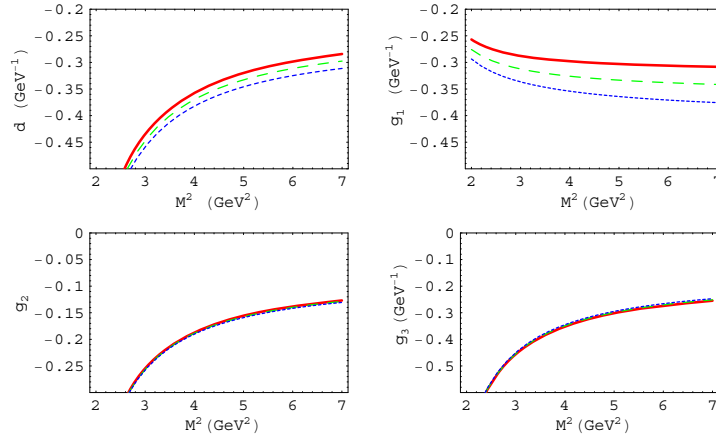


Figure 2: Sum rule results for the hadronic parameters in eqs.(2.1)-(2.4). M^2 is the Borel parameter.

a description of the mesons as quark-antiquark states, we consider it as a quantitative argument in support of a $\bar{c}s$ interpretation of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$. The observation of all the radiative decay modes with the predicted relative rates would reinforce the conclusion. In order to quantitatively understand the experimental data in Table 2 one should precisely know the widths of the isospin violating transitions $D_{s0} \rightarrow D_s \pi^0$ and $D'_{s1} \rightarrow D_s^* \pi^0$. In the description of these transitions based on the mechanism of $\eta - \pi^0$ mixing [13, 4, 5, 6] one should accurately determine the strong couplings $D_{s0} D_s \eta$ and $D'_{s0} D_s^* \eta$ for finite heavy quark mass and including $SU(3)$ corrections.

3. Narrow states in the beauty sector

The mass extrapolation from charm to beauty and the interpretation of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ as ordinary mesons allow to predict the masses of corresponding states in the beauty sector: $M(B_{s0}) = 5.71 \pm 0.03 \text{ GeV}$ and $M(B'_{s1}) = 5.77 \pm 0.03 \text{ GeV}$ [14]. Therefore, B_{s0} and B'_{s1} should be respectively below the BK and B^*K thresholds; they should be observed as narrow peaks in $B_s \pi^0$ and $B_s^* \pi^0$, $B_s^{(*)} \gamma$ invariant mass distributions, a possible observation at the Tevatron and the LHC.

Table 1: Radiative decay widths (in keV) of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ obtained by Light-Cone sum rules (LCSR). Vector Meson Dominance (VMD) and constituent quark model (QM) results are also reported.

Initial state	Final state	LCSR [7]	VMD [2, 6]	QM [5]	QM [8]
$D_{sJ}^*(2317)$	$D_s^*\gamma$	4-6	0.85	1.9	1.74
$D_{sJ}(2460)$	$D_s\gamma$	19-29	3.3	6.2	5.08
	$D_s^*\gamma$	0.6-1.1	1.5	5.5	4.66
	$D_{sJ}^*(2317)\gamma$	0.5-0.8	—	0.012	2.74

Table 2: Measurements and 90% CL upper limits of ratios of $D_{sJ}^*(2317)$ and $D_{sJ}(2460)$ decay widths.

	Belle	BaBar	CLEO
$\Gamma(D_{sJ}^*(2317) \rightarrow D_s^*\gamma) / \Gamma(D_{sJ}^*(2317) \rightarrow D_s\pi^0)$	< 0.18	—	< 0.059
$\Gamma(D_{sJ}(2460) \rightarrow D_s\gamma) / \Gamma(D_{sJ}(2460) \rightarrow D_s\pi^0)$	0.45 ± 0.09	0.30 ± 0.04	< 0.49
$\Gamma(D_{sJ}(2460) \rightarrow D_s^*\gamma) / \Gamma(D_{sJ}(2460) \rightarrow D_s\pi^0)$	< 0.31	—	< 0.16
$\Gamma(D_{sJ}(2460) \rightarrow D_{sJ}^*(2317)\gamma) / \Gamma(D_{sJ}(2460) \rightarrow D_s\pi^0)$	—	< 0.23	< 0.58

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