Cabibbo-suppressed nonleptonic *B* and *D* decays involving tensor mesons

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The Cabibbo-suppressed nonleptonic decays of B (and D) mesons to final states involving tensor mesons are computed using the nonrelativistic quark model of Isgur, Scora, Grinstein, and Wise with the factorization hypothesis. We find that some of these B decay modes, such as $B\to(K^*,D^*)D_2^*$, can have branching ratios as large as 6×10^{-5}, which seems to be at the reach of future B factories. [S0556-2821(99)02907-0]

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I. INTRODUCTION

B meson factories at SLAC and KEK will soon start their operation. In addition to the central interest on the study of CP violation in the B system, the precision of many properties of B mesons that have already been measured is expected to be improved there. Some suppressed decays of B mesons, either modes occurring at the tree level and suppressed by Cabibbo-Kobayashi-Maskawa (CKM) factors or modes suppressed by dynamical effects, will certainly be accessible at these experiments for the first time. Another kind of suppressed B decay corresponds to the modes containing mesons that are radial or orbital excitations of the $q\overline{q'}$ system. Semileptonic B decays containing orbital excitations of the $c\overline{q}$ system, as D_1 and D_2^* mesons, have been observed recently by CLEO [1], who concluded that they can account for up to 20% of the B semileptonic rate. The study of these decays is interesting to probe the specific predictions for the hadronic matrix elements in the context of phenomenological quark models [2] and heavy quark effective theory [3–5].

In a recent paper [6] we have computed the Cabibbo-favored nonleptonic decay modes of B mesons of the form $B\to PT,VT$, where $P(V)$ is a pseudoscalar (vector) meson and the spin-two tensor meson T corresponds to the p wave of the quark-antiquark system. We have found [6] that some of these decay modes have branching ratios large enough to be observed in future measurements. Similar conclusions have been reached in Refs. [7,8].

In the present paper we consider the Cabibbo-suppressed two-body nonleptonic decay modes of B mesons that contain a light- or charmed-tensor meson in the final state. Despite additional Cabibbo-suppression factors, the amplitudes for some of these decays can be enhanced because they are favored by contributions proportional to the a_1 QCD coefficient which appears in the effective weak Hamiltonian and/or have more phase space available. We make use of the nonrelativistic quark model of Ref. [2] to evaluate the relevant hadronic matrix elements of the $B\to T$ transitions, where T is a light or heavy (i.e., charmed) tensor meson. For completeness, we also compute the Cabibbo-suppressed two-body nonleptonic D decays involving tensor mesons that are allowed by phase space considerations. The corresponding Cabibbo-favored D decays have been computed in Ref. [9].

Let us mention that the $B\to T$ hadronic matrix element computed in Ref. [2] has been used recently to evaluate the semileptonic rate of the $B\to D_2^* l\nu$ [5] decay mode. The heavy quark effective theory also allows a computation of the $B\to T$ matrix element and has been used to evaluate the decay rates of the $B^-\to D_2^{*0}\pi^-$ [8] (see also Ref. [3]) and $B\to D_2^* l\nu$ [3–5] decays.

Besides the interest of heavy meson decays to tensor mesons in order to test properties of quark models or symmetries of QCD for heavy quarks, one should mention that tensor mesons (i.e., $q\overline{q'}$ states with $L=1$, $S=1$, and $J^P=2^+$) belong to one of the better established 16-plet under flavor SU(4). Indeed, according to the compilation of the Particle Data Group [10], the following members of the 16-plet of tensor mesons have already been observed: the isovector $a_2(1320)$ state, the isoscalars $f_2(1270)$, $f_2'(1525)$, and $\chi_{c2}(3556)$, the strange isospinor $K_2^*(1430)$, and the charm isodoublet $D_2^*(2460)$ states. Although there is not compelling evidence yet for the charmed-strange tensor meson, according to the latest data given in the current Particle Data Group (PDG) paper [11] the $D_{sJ}^*(2573)$ has the width and decay modes consistent with a $J^P=2^+$ $c\overline{s}$ state.

Despite their low branching fractions, the observation of some nonleptonic Cabibbo-suppressed B and D decays to lowest lying mesons have been reported recently. For example, the following decay modes have been observed: $B^-\to D^0K^-$ [12], $B^0\to D^{*+}D^{*-}$ [13], $D^0\to K^-K^*,\pi^+\pi^-$ [14], and $D^+\to(\eta,\eta')\pi^+,(\eta,\eta')\rho^+$ [15]. As will be shown below, some Cabibbo-suppressed B decays to tensor mesons have branching ratios of order 10^{-5}–10^{-6} which look to be not too far from experimental searches at B factories.

The rest of the paper is organized as follows. In Sec. II we write the effective nonleptonic weak Hamiltonians for Cabibbo-suppressed B and D decays and provide a classification for these decays. In Sec. III we set our convention for mixing of octet and singlet states of SU(3) and provide the numerical values of the parameters required for our calculations. Our conclusions are given in Sec. IV. Let us note that we closely follow the notation and formulas obtained in Ref. [6].

TABLE I. Decay amplitudes and branching ratios for the CKM-suppressed $B\to PT$ channels of type I with $\Delta s=0,-1$. These amplitudes must be multiplied by $(iG_F/\sqrt{2})\varepsilon^*_{\mu\nu}p^\mu_B p^\nu_B$.

Process	Amplitude $\times(V_{ub}V^*_{ud})$	$Br(B\to PT)$
	$\Delta s=0$	
$B^-\to\pi^-a_2^0$	$a_1 f_{\pi^-}\mathcal{F}^{B\to a_2}(m^2_{\pi^-})/\sqrt{2}$	3.02×10^{-7}
$B^-\to\pi^-f_2$	$a_1 f_{\pi^-}\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_{\pi^-})/\sqrt{2}$	3.25×10^{-7}
$B^-\to\pi^-f_2'$	$a_1 f_{\pi^-}\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_{\pi^-})/\sqrt{2}$	3.23×10^{-9}
$B^-\to\pi^0a_2^-$	$a_2 f_{\pi^0}\mathcal{F}^{B\to a_2}(m^2_{\pi^0})/\sqrt{2}$	1.52×10^{-8}
$B^-\to\eta a_2^-$	$a_2 f_\eta\sin\phi_P\mathcal{F}^{B\to a_2}(m^2_\eta)/\sqrt{2}$	1.05×10^{-8}
$B^-\to\eta' a_2^-$	$a_2 f_{\eta'}\cos\phi_P\mathcal{F}^{B\to a_2}(m^2_{\eta'})/\sqrt{2}$	4.18×10^{-9}
$\overline{B^0}\to\pi^-a_2^+$	$a_1 f_{\pi^-}\mathcal{F}^{B\to a_2}(m^2_{\pi^-})$	5.71×10^{-7}
$\overline{B^0}\to\pi^0a_2^0$	$-a_2 f_{\pi^0}\mathcal{F}^{B\to a_2}(m^2_{\pi^0})/2$	7.18×10^{-9}
$\overline{B^0}\to\pi^0f_2$	$a_2 f_{\pi^0}\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_{\pi^0})/2$	7.72×10^{-9}
$\overline{B^0}\to\pi^0f_2'$	$a_2 f_{\pi^0}\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_{\pi^0})/2$	7.68×10^{-11}
$\overline{B^0}\to\eta a_2^0$	$-a_2 f_\eta\sin\phi_P\mathcal{F}^{B\to a_2}(m^2_\eta)/2$	4.98×10^{-9}
$\overline{B^0}\to\eta f_2$	$a_2 f_\eta\sin\phi_P\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_\eta)/2$	5.36×10^{-9}
$\overline{B^0}\to\eta f_2'$	$a_2 f_\eta\sin\phi_P\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_\eta)/2$	5.31×10^{-11}
$\overline{B^0}\to\eta' a_2^0$	$-a_2 f_{\eta'}\cos\phi_P\mathcal{F}^{B\to a_2}(m^2_{\eta'})/2$	1.98×10^{-9}
$\overline{B^0}\to\eta' f_2$	$a_2 f_{\eta'}\cos\phi_P\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_{\eta'})/2$	2.13×10^{-9}
$\overline{B^0}\to\eta' f_2'$	$a_2 f_{\eta'}\cos\phi_P\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_{\eta'})/2$	2.08×10^{-11}
	$\Delta s=1$	
Process	Amplitude $\times(V_{ub}V^*_{cs})$	
$B^-\to D_s^-a_2^0$	$a_1 f_{D_s^-}\mathcal{F}^{B\to a_2}(m^2_{D_s^-})/\sqrt{2}$	1.45×10^{-6}
$B^-\to D_s^-f_2$	$a_1 f_{D_s^-}\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_{D_s^-})/\sqrt{2}$	1.58×10^{-6}
$B^-\to D_s^-f_2'$	$a_1 f_{D_s^-}\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_{D_s^-})/\sqrt{2}$	1.43×10^{-8}
$B^-\to\overline{D}^0K_2^{*-}$	$a_2 f_{D^0}\mathcal{F}^{B\to K_2^*}(m^2_{D^0})$	6.38×10^{-8}
$\overline{B^0}\to D_s^-a_2^+$	$a_1 f_{D_s^-}\mathcal{F}^{B\to a_2}(m^2_{D_s^-})$	2.75×10^{-6}
$\overline{B^0}\to\overline{D}^0\overline{K}_2^{*0}$	$a_2 f_{D^0}\mathcal{F}^{B\to K_2^*}(m^2_{D^0})$	5.90×10^{-8}

II. EFFECTIVE WEAK HAMILTONIANS FOR CABIBBO-SUPPRESSED *B* AND *D* DECAYS

The B and D decays of our interest are such that only one single Cabibbo suppression factor occurs at a time. The effective weak Hamiltonian for single Cabibbo-suppressed nonleptonic B decays can be written as follows:

$$\mathcal{H}_{\rm eff}(\Delta b)=\frac{G_F}{\sqrt{2}}\{V_{ub}V^*_{ud}[a_1(\overline{u}b)(\overline{d}u)+a_2(\overline{d}b)(\overline{u}u)] +V_{ub}V^*_{cs}[a_1(\overline{u}b)(\overline{s}c)+a_2(\overline{s}b)(\overline{u}c)] +V_{cb}V^*_{cd}[a_1(\overline{c}b)(\overline{d}c)+a_2(\overline{d}b)(\overline{c}c)] +V_{cb}V^*_{us}[a_1(\overline{c}b)(\overline{s}u)+a_2(\overline{s}b)(\overline{c}u)]\}+\text{H.c.}, \tag{1}$$

where $(\overline{q}q')$ is a short notation for the V-A current, G_F denotes the Fermi constant, and V_{ij} are the relevant CKM mixing factors. In this paper we will take the following numerical values for the QCD coefficients: $a_1=1.15$, $a_2=0.26$ [16].

TABLE II. Decay amplitudes and branching ratios for the CKM-suppressed $B\to PT$ decays of type II with $\Delta s=0,-1$. The amplitudes must be multiplied by $(iG_F/\sqrt{2})\varepsilon^*_{\mu\nu}p^\mu_B p^\nu_B$.

Process	Amplitude $\times(V_{cb}V^*_{cd})$	$Br(B\to PT)$
	$\Delta s=0$	
$B^-\to D^-D_2^{*0}$	$a_1 f_{D^-}\mathcal{F}^{B\to D_2^*}(m^2_{D^-})$	1.76×10^{-5}
$B^-\to\eta_c a_2^-$	$a_2 f_{\eta_c}\mathcal{F}^{B\to a_2}(m^2_{\eta_c})$	1.44×10^{-6}
$\overline{B^0}\to D^-D_2^{*+}$	$a_1 f_{D^-}\mathcal{F}^{B\to D_2^*}(m^2_{D^-})$	1.66×10^{-5}
$\overline{B^0}\to\eta_c a_2^0$	$-a_2 f_{\eta_c}\mathcal{F}^{B\to a_2}(m^2_{\eta_c})/\sqrt{2}$	6.80×10^{-7}
$\overline{B^0}\to\eta_c f_2$	$a_2 f_{\eta_c}\cos\phi_T\mathcal{F}^{B\to f_2}(m^2_{\eta_c})/\sqrt{2}$	7.77×10^{-7}
$\overline{B^0}\to\eta_c f_2'$	$a_2 f_{\eta_c}\sin\phi_T\mathcal{F}^{B\to f_2'}(m^2_{\eta_c})/\sqrt{2}$	5.07×10^{-9}
	$\Delta s=-1$	
Process	Amplitude $\times(V_{cb}V^*_{us})$	
$B^-\to K^-D_2^{*0}$	$a_1 f_{K^-}\mathcal{F}^{B\to D_2^*}(m^2_{K^-})$	2.40×10^{-5}
$B^-\to D^0K_2^{*-}$	$a_2 f_{D^0}\mathcal{F}^{B\to K_2^*}(m^2_{D^0})$	4.56×10^{-7}
$\overline{B^0}\to K^-D_2^{*+}$	$a_1 f_{K^-}\mathcal{F}^{B\to D_2^*}(m^2_{K^-})$	2.27×10^{-5}
$\overline{B^0}\to D^0\overline{K}_2^{*0}$	$a_2 f_{D^0}\mathcal{F}^{B\to K_2^*}(m^2_{D^0})$	4.22×10^{-7}

In order to provide a classification for the wide set of these decays, we will call those occurring through the first two terms within curly brackets type I decays (i.e., proportional to V_{ub}) while those proportional to V_{cb} will be called type II. Based on current values of CKM matrix elements, one would naively expect that type I B decay branching ratios are suppressed by the factor $|V_{ub}/V_{cb}V_{us}|^2\approx0.13$ with respect to type II decays. Among type I and II decays we will also distinguish between processes with $\Delta s=0,1$ associated to the change of strangeness in the second weak vertex.

In a similar way, the effective weak Hamiltonian for single Cabibbo-suppressed D decays is given by

$$\mathcal{H}_{\rm eff}(\Delta c)=\frac{G_F}{\sqrt{2}}V_{cd}V^*_{ud}\{a_1(\overline{d}c)(\overline{u}d)+a_2(\overline{u}c)(\overline{d}d)\}+\text{H.c.}, \tag{2}$$

where the numerical values for the QCD coefficients will be taken as $a_1=1.26$ and $a_2=-0.51$ [17]. Notice that we have included only the terms relevant for D decays with $\Delta s=0$ (type I), because type II transitions are very suppressed by phase space considerations. Note that $D\to VT$ are completely forbidden by kinematics.

Observe that due to the vector nature of the effective hadronic weak currents in Eqs. (1),(2), the matrix element $\langle T|\overline{q}q'|0\rangle$ vanishes identically. Therefore, as already discussed in Ref. [6], only one operator in the effective weak Hamiltonian will contribute to the decay amplitude of a

TABLE III. Decay amplitudes and branching ratios for the CKM-suppressed $B\to VT$ modes of type I with $\Delta s=0,-1$. The amplitudes must be multiplied by $(G_F/\sqrt{2})\varepsilon^{*\mu\nu}$.

Process	Amplitude $\times(V_{ub}V_{ud}^*)$	$Br(B\to VT)$
	$\Delta s=0$	
$B^-\to\rho^- a_2^0$	$a_1 f_{\rho^-} m_{\rho^-}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{\rho^-}^2)/\sqrt{2}$	8.66×10^{-7}
$B^-\to\rho^- f_2$	$a_1 f_{\rho^-} m_{\rho^-}^2 \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_{\rho^-}^2)/\sqrt{2}$	9.22×10^{-7}
$B^-\to\rho^- f_2'$	$a_1 f_{\rho^-} m_{\rho^-}^2 \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_{\rho^-}^2)/\sqrt{2}$	9.83×10^{-9}
$B^-\to\rho^0 a_2^-$	$a_2 f_{\rho^0} m_{\rho^0}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{\rho^0}^2)/\sqrt{2}$	4.43×10^{-8}
$B^-\to\omega a_2^-$	$a_2 f_\omega m_\omega^2 \cos\phi_V \mathcal{F}_{\mu\nu}^{B\to a_2}(m_\omega^2)/\sqrt{2}$	3.59×10^{-8}
$B^-\to\phi a_2^-$	$a_2 f_\phi m_\phi^2 \sin\phi_V \mathcal{F}_{\mu\nu}^{B\to a_2}(m_\phi^2)/\sqrt{2}$	2.31×10^{-10}
$\overline{B^0}\to\rho^- a_2^+$	$a_1 f_{\rho^-} m_{\rho^-}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{\rho^-}^2)$	1.64×10^{-6}
$\overline{B^0}\to\rho^0 a_2^0$	$-a_2 f_{\rho^0} m_{\rho^0}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{\rho^0}^2)/2$	2.09×10^{-8}
$\overline{B^0}\to\rho^0 f_2$	$a_2 f_{\rho^0} m_{\rho^0}^2 \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_{\rho^0}^2)/2$	2.23×10^{-8}
$\overline{B^0}\to\rho^0 f_2'$	$a_2 f_{\rho^0} m_{\rho^0}^2 \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_{\rho^0}^2)/2$	2.38×10^{-10}
$\overline{B^0}\to\omega a_2^0$	$-a_2 f_\omega m_\omega^2 \cos\phi_V \mathcal{F}_{\mu\nu}^{B\to a_2}(m_\omega^2)/2$	1.70×10^{-8}
$\overline{B^0}\to\omega f_2$	$a_2 f_\omega m_\omega^2 \cos\phi_V \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_\omega^2)/2$	2.42×10^{-8}
$\overline{B^0}\to\omega f_2'$	$a_2 f_\omega m_\omega^2 \cos\phi_V \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_\omega^2)/2$	1.93×10^{-10}
$\overline{B^0}\to\phi a_2^0$	$-a_2 f_\phi m_\phi^2 \sin\phi_V \mathcal{F}_{\mu\nu}^{B\to a_2}(m_\phi^2)/2$	1.09×10^{-10}
$\overline{B^0}\to\phi f_2$	$a_2 f_\phi m_\phi^2 \sin\phi_V \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_\phi^2)/2$	1.16×10^{-10}
$\overline{B^0}\to\phi f_2'$	$a_2 f_\phi m_\phi^2 \sin\phi_V \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_\phi^2)/2$	1.29×10^{-12}
	$\Delta s=-1$	
Process	Amplitude $\times(V_{ub}V_{cs}^*)$	
$B^-\to D_s^{*-} a_2^0$	$a_1 f_{D_s^{*-}} m_{D_s^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{D_s^{*-}}^2)/\sqrt{2}$	2.13×10^{-6}
$B^-\to D_s^{*-} f_2$	$a_1 f_{D_s^{*-}} m_{D_s^{*-}}^2 \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_{D_s^{*-}}^2)/\sqrt{2}$	2.17×10^{-6}
$B^-\to D_s^{*-} f_2'$	$a_1 f_{D_s^{*-}} m_{D_s^{*-}}^2 \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_{D_s^{*-}}^2)/\sqrt{2}$	2.98×10^{-8}
$B^-\to\overline{D}^{*0} K_2^{*-}$	$a_2 f_{D^{*0}} m_{D^{*0}}^2 \mathcal{F}_{\mu\nu}^{B\to K_2^{*-}}(m_{D^{*0}}^2)$	3.14×10^{-7}
$\overline{B^0}\to D_s^{*-} a_2^+$	$a_1 f_{D_s^{*-}} m_{D_s^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{D_s^{*-}}^2)$	4.03×10^{-6}
$\overline{B^0}\to\overline{D}^{*0}\overline{K}_2^{*0}$	$a_2 f_{D^{*0}} m_{D^{*0}}^2 \mathcal{F}_{\mu\nu}^{B\to K_2^*}(m_{D^{*0}}^2)$	2.95×10^{-7}

given process, i.e., the amplitudes for our processes become proportional to either a_1 or a_2 alone.

III. MIXING OF STATES, DECAY CONSTANTS, AND RESULTS

In this section we provide our convention for SU(3) octet-singlet mixing of states and the numerical values for the decay constants required to describe the $\langle P(V)|(\overline{q}q')|0\rangle$ matrix elements. As is known, the breaking of SU(3) flavor symmetry produces a mixing between octet and singlet states of SU(3) with $I=0$. In our convention, this mixing leads to the following expressions for the physical states:

$$\eta=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\sin\phi_P-(s\overline{s})\cos\phi_P,$$

$$\eta'=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\cos\phi_P+(s\overline{s})\sin\phi_P,$$

$$\omega=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\cos\phi_V+(s\overline{s})\sin\phi_V,$$

$$\phi=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\sin\phi_V-(s\overline{s})\cos\phi_V, \qquad (3)$$

$$f_2=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\cos\phi_T+(s\overline{s})\sin\phi_T,$$

$$f_2'=\frac{1}{\sqrt{2}}(u\overline{u}+d\overline{d})\sin\phi_T-(s\overline{s})\cos\phi_T,$$

where the mixing angle is given by $\phi_i=\arctan(1/\sqrt{2})-\theta_i$ ($i=P,V$ or T) and the experimental values of θ_i are given by $-20°$, $39°$, and $28°$ [10] for pseudoscalar (η,η'), vector (ω,ϕ), and tensor (f_2,f_2') mesons, respectively.

With the above convention, we have computed the decay amplitudes for type I and II $B\to P(V)+T$ decays and the results are given in the third column of Tables I–IV. The analogous results for type I $D\to P+T$ transitions are given in the third column of Table V. As already mentioned, these amplitudes are proportional to only one QCD coefficient appearing in the weak Hamiltonians. The explicit expressions for the functions $\mathcal{F}^{i\to f}$ and $\mathcal{F}_{\mu\nu}^{i\to f}$ appearing in the decay amplitudes and the properties of the symmetric polarizations tensors $\epsilon_{\mu\nu}$ describing the spin 2 particles can be found in Ref. [6].

TABLE IV. Decay amplitudes and branching ratios for the CKM-suppressed $B\to VT$ decays of type II with $\Delta s=0,-1$. The amplitudes must be multiplied by $(G_F/\sqrt{2})\varepsilon^{*\mu\nu}$.

Process	Amplitude $\times(V_{cb}V_{cd}^*)$	$Br(B\to VT)$
	$\Delta s=0$	
$B^-\to D^{*-}D_2^{*0}$	$a_1 f_{D^{*-}} m_{D^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to D_2^*}(m_{D^{*-}}^2)$	6.66×10^{-5}
$B^-\to J/\psi a_2^-$	$a_2 f_{J/\psi} m_{J/\psi}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{J/\psi}^2)$	5.23×10^{-6}
$\overline{B^0}\to D^{*-}D_2^{*+}$	$a_1 f_{D^{*-}} m_{D^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to D_2^*}(m_{D^{*-}}^2)$	6.29×10^{-5}
$\overline{B^0}\to J/\psi a_2^0$	$-a_2 f_{J/\psi} m_{J/\psi}^2 \mathcal{F}_{\mu\nu}^{B\to a_2}(m_{J/\psi}^2)/\sqrt{2}$	2.47×10^{-6}
$\overline{B^0}\to J/\psi f_2$	$a_2 f_{J/\psi} m_{J/\psi}^2 \cos\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2}(m_{J/\psi}^2)/\sqrt{2}$	2.56×10^{-6}
$\overline{B^0}\to J/\psi f_2'$	$a_2 f_{J/\psi} m_{J/\psi}^2 \sin\phi_T \mathcal{F}_{\mu\nu}^{B\to f_2'}(m_{J/\psi}^2)/\sqrt{2}$	2.92×10^{-8}
	$\Delta s=-1$	
Process	Amplitude $\times(V_{cb}V_{us}^*)$	
$B^-\to K^{*-}D_2^{*0}$	$a_1 f_{K^{*-}} m_{K^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to D_2^*}(m_{K^{*-}}^2)$	5.77×10^{-5}
$B^-\to D^{*0}K_2^{*-}$	$a_2 f_{D^{*0}} m_{D^{*0}}^2 \mathcal{F}_{\mu\nu}^{B\to K_2^*}(m_{D^{*0}}^2)$	2.24×10^{-6}
$\overline{B^0}\to K^{*-}D_2^{*+}$	$a_1 f_{K^{*-}} m_{K^{*-}}^2 \mathcal{F}_{\mu\nu}^{B\to D_2^*}(m_{K^{*-}}^2)$	5.46×10^{-5}
$\overline{B^0}\to D^{*0}\overline{K}_2^{*0}$	$a_2 f_{D^{*0}} m_{D^{*0}}^2 \mathcal{F}_{\mu\nu}^{B\to K_2^*}(m_{D^{*0}}^2)$	2.11×10^{-6}

TABLE V. Decay amplitudes and branching ratios for the CKM-suppressed $D\to PT$ channels of type I with $\Delta s=0$. The amplitudes must be multiplied by $(iG_F/\sqrt{2})\varepsilon^*_{\mu\nu}p^\mu_D p^\nu_D$.

Process	$\Delta s=0$ Amplitude $\times(V_{cd}V^*_{ud})$	$Br(D\to PT)$
$D^0\to\pi^+a_2^-$	$a_1 f_{\pi^+}\mathcal{F}^{D\to a_2}(m^2_{\pi^+})$	4.21×10^{-6}
$D^0\to\pi^0a_2^0$	$-a_2 f_{\pi^0}\mathcal{F}^{D\to a_2}(m^2_{\pi^0})/2$	1.72×10^{-7}
$D^0\to\pi^0 f_2$	$-a_2 f_{\pi^0}\cos\phi_T\mathcal{F}^{D\to f_2}(m^2\pi^0)/2$	2.47×10^{-7}
$D^0\to\pi^0 f_2'$	$-a_2 f_{\pi^0}\sin\phi_T\mathcal{F}^{D\to f_2'}(m^2_{\pi^0})/2$	2.18×10^{-10}
$D^+\to\pi^+a_2^0$	$-a_1 f_{\pi^+}\mathcal{F}^{D\to a_2}(m^2_{\pi^+})/\sqrt{2}$	5.55×10^{-6}
$D^+\to\pi^+ f_2$	$a_1 f_{\pi^+}\cos\phi_T\mathcal{F}^{D\to f_2}(m^2_{\pi^+})/\sqrt{2}$	7.97×10^{-6}
$D^+\to\pi^+ f_2'$	$a_1 f_{\pi^+}\sin\phi_T\mathcal{F}^{D\to f_2'}(m^2_{\pi^+})/\sqrt{2}$	7.18×10^{-9}
$D^+\to\pi^0a_2^+$	$-a_2 f_{\pi^0}\mathcal{F}^{D\to a_2}(m^2_{\pi^0})/\sqrt{2}$	9.05×10^{-7}

In order to provide numerical values of the branching ratios we use the expressions for the decay rates given in Eqs. (9) and (11) of Ref. [6] and the following values of the CKM matrix elements [10]: $|V_{ub}|=3.3\times10^{-3}$, $|V_{ud}|=0.9740$, $|V_{cs}|=0.975$, $|V_{cb}|=0.0395$, $|V_{cd}|=0.224$, and $|V_{us}|=0.2196$. The values for the lifetimes of B and D mesons are taken from Ref. [10].

The decay constants of pseudoscalar mesons f_P (given in GeV units) have the following central values: $f_{\pi^-}=0.131$ [10], $f_{\pi^0}=0.130$ [10], $f_\eta=0.131$ [18], $f_{\eta'}=0.118$ [18], $f_{D_s}=0.280$ [19], $f_D=0.252$, $f_{\eta_c}=0.393$ [20], and $f_{K^+}=0.159$ [10]. f_D is obtained using the theoretical prediction $f_D/f_{D_s}=0.90$ [21] and the value for f_{D_s}. On the other hand, the central values for the dimensionless decay constants of vector mesons f_V are [20] $f_\rho=0.281$, $f_\omega=0.249$, $f_\phi=0.232$, $f_{D_s^*}=0.128$, $f_{D^*}=0.124$, $f_{J/\psi}=0.1307$, and $f_{K^*}=0.248$. The branching ratios for Cabibbo-suppressed B and D decays involving tensor mesons are given in the last column of Tables I–V.

IV. CONCLUSIONS

Semileptonic B decays to final states containing orbital excitations of the $q\overline{q'}$ system have already been observed in recent experimental searches. These suppressed decay modes are expected to provide additional tests of the QCD dynamics exhibited by phenomenological quark models or the heavy quark effective theory predictions for the hadronic matrix elements involving higher excitations of the $q\overline{q'}$ system.

Based on the nonrelativistic quark model of Ref. [2], in this paper we have computed the Cabibbo-suppressed decay modes of B (and D) mesons to final states involving $J^P=2^+$ tensor mesons. As observed in Table IV, some of these B decays as $B^-\to(D^{*-},K^{*-})D_2^{*0}$ and $\overline{B^0}\to(D^{*-},K^{*-})D_2^{*+}$ can have branching ratios as large as 6×10^{-5}, which seems to be at the reach of future B factories. Despite the fact that these modes have a Cabibbo-suppression factor, they exhibit branching fractions comparable to some corresponding Cabibbo-allowed B decays (see, for example, Refs. [6,7]) because they are proportional to the a_1 coefficients (instead of a_2) and the available phase space is larger. Regarding $D\to PT$ transitions, the most favored decay modes correspond to $D\to\pi^+(a_2,f_2)$ with branching fractions in the range $(4\sim8)\times10^{-6}$.

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