Study of $B_{u,d,s} \to SS$ decays within QCD factorization

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effective weak Hamiltonian

$$\mathcal{H}_{\text{eff}} = \frac{G_F}{\sqrt{2}}\Bigg[V_{ub}V_{up}^*\,(C_1 O_1^u + C_2 O_2^u) + V_{cb}V_{cp}^*\,(C_1 O_1^c + C_2 O_2^c) - V_{tb}V_{tp}^*\,\Big(\sum_{i=3}^{10} C_i O_i + C_{7\gamma} O_{7\gamma} + C_{8g} O_{8g}\Big)\Bigg] + \text{h.c.}, \qquad (1)$$

where $V_{qb}V_{qp}^*$ $(q = u, c$ and $t)$

coefficients of flavor operators α_i^p

$$\alpha_1(M_1M_2) = a_1(M_1M_2), \qquad \alpha_2(M_1M_2) = a_2(M_1M_2), \tag{2}$$

$$\alpha_3^p(M_1M_2) = a_3^p(M_1M_2) + a_5^p(M_1M_2) \quad \text{if } M_1M_2 = SS, \tag{3}$$

$$\alpha_4^p(M_1M_2) = a_4^p(M_1M_2) + \bar{r}_\chi^{M_2} a_6^p(M_1M_2) \quad \text{if } M_1M_2 = SS, \tag{4}$$

$$\alpha_{3,EW}^p(M_1M_2) = a_9^p(M_1M_2) + a_7^p(M_1M_2) \quad \text{if } M_1M_2 = SS, \tag{5}$$

$$\alpha_{4,EW}^p(M_1M_2) = a_{10}^p(M_1M_2) + \bar{r}_\chi^{M_2} a_8^p(M_1M_2) \quad \text{if } M_1M_2 = SS\,, \tag{6}$$

where the ratio $\bar{r}_\chi$ is defined as

$$\bar{r}_\chi^{K_0^*}(\mu) = \frac{2m_{K_0^*}}{m_b(\mu)}\,, \bar{r}_\chi^{a_0}(\mu) = \frac{2m_{a_0}}{m_b(\mu)}\,. \tag{7}$$

Input parameters

For the decay constant(unit is MeV),ScaleMu = 1 GeV

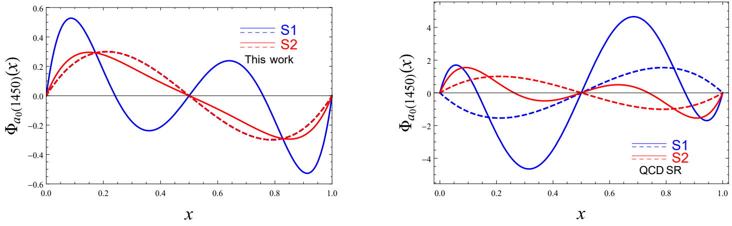
$$\bar{f}_{K_0^*(1430)} = 256 \pm 3 \quad S1, \qquad \bar{f}_{K_0^*(1430)} = 301 \pm 18 \quad S2,$$
$$\bar{f}_{a_0(1450)} = 245 \pm 2 \quad S1, \qquad \bar{f}_{a_0(1450)} = 314 \pm 24 \quad S2,$$
$$f_{B_{u,d}} = 186 \pm 7, \qquad f_{B_s} = 224 \pm 9,$$

Table: Form factors of $B \to K_0^*(1430), a_0(1450)$ and $B_s \to K_0^*(1430), a_0(1450)$ transitions in S1 (lower entry) and S2 (upper entry) .

F	$F(0)$	a	b	F	$F(0)$	a	b
$U_1^{B\to K_0^*}$	0.29 ± 0.02	1.27	0.33	$U_0^{B\to K_0^*}$	0.29 ± 0.02	0.16	0.11
	0.18 ± 0.01	1.03	0.15		0.18 ± 0.01	-0.23	0.29
$U_1^{B_s\to K_0^*}$	0.28 ± 0.02	1.58	0.84	$U_0^{B_s\to K_0^*}$	0.28 ± 0.02	0.55	0.20
	0.23 ± 0.02	0.92	0.29		0.23 ± 0.02	-0.23	0.36
$U_1^{B\to a_0}$	0.29 ± 0.02	1.57	0.70	$U_0^{B\to a_0}$	0.29 ± 0.02	0.55	0.03
	0.26 ± 0.01	1.66	1.00		0.26 ± 0.01	0.73	0.09
$U_1^{B_s\to a_0}$	0.29 ± 0.02	1.52	0.64	$U_0^{B_s\to a_0}$	0.29 ± 0.02	0.44	0.05
	0.26 ± 0.02	1.59	0.91		0.26 ± 0.02	0.59	0.09

Table: Gegenbauer moments of $K_0^*(1430)$,$a_0(1450)$ at $\mu = 1\mathrm{GeV}$ in S1 (lower entry) and S2 (upper entry).

This work	b_0	b_1	b_2	b_3
$K_0^*(1430)$	0.08 ± 0.01	-0.13 ± 0.05	-0.03 ± 0.00	-0.01 ± 0.00
	0.08 ± 0.01	-0.15 ± 0.05	0.06 ± 0.01	-0.09 ± 0.05
$a_0(1450)$	0	-0.17 ± 0.03	0	-0.03 ± 0.01
	0	-0.17 ± 0.06	0	-0.19 ± 0.03
QCD SR	b_0	b_1	b_2	b_3
$K_0^*(1430)$	0	-0.57 ± 0.13	0	-0.42 ± 0.22
	0	0.58 ± 0.07	0	-1.20 ± 0.08
$a_0(1450)$	0	-0.58 ± 0.12	0	-0.49 ± 0.15
	0	0.89 ± 0.20	0	-1.38 ± 0.18



(a) (b)

Numerical results and discussions

Table: The branching fractions (in units of 10^{-6}) of $B_{u,d,s} \to M_1 M_2$ decays .

	$(\rho_{i,f}, \phi_{i,f}) = (1, -55)$		$(\rho_i, \phi_i) = (2.97, -105)$ $(\rho_f, \phi_f) = (2.8, 165)$		PQCD (LiuXin)	
Decay modes	S2	S1	S2	S1	S2	S1
$\bar{B}_s^0 \to a_0^- a_0^+$	0.052	0.082	0.29	0.64	3.55	5.63
$\bar{B}_s^0 \to a_0^0 a_0^0$	0.026	0.041	0.15	0.32		
$\bar{B}_s^0 \to a_0^- K_0^{*+}$	36.01	15.02	35.56	15.18		
$\bar{B}_s^0 \to a_0^0 K_0^{*0}$	0.55	0.27	0.58	0.58		
$\bar{B}_s^0 \to K_0^{*-} K_0^{*+}$	11.37	6.77	4.90	4.94	520	230
$\bar{B}_s^0 \to \bar{K}_0^{*0} K_0^{*0}$	12.73	7.51	4.78	3.66	540	250
$\bar{B}_d^0 \to a_0^- a_0^+$	36.62	18.27	32.27	15.72		
$\bar{B}_d^0 \to a_0^0 a_0^0$	1.10	0.65	1.76	1.77		
$\bar{B}_d^0 \to a_0^+ K_0^{*-}$	11.31	7.92	6.01	5.47		
$\bar{B}_d^0 \to a_0^0 \bar{K}_0^{*0}$	3.90	3.39	1.76	2.29		
$\bar{B}_d^0 \to K_0^{*-} K_0^{*+}$	0.01	0.01	0.06	0.07	2.2	3.2
$\bar{B}_d^0 \to K_0^{*0} \bar{K}_0^{*0}$	0.59	0.21	0.27	0.12	20	11
$B^- \to a_0^0 a_0^-$	24.83	12.06	25.40	12.50		
$B^- \to a_0^- \bar{K}_0^{*0}$	13.60	9.41	6.21	4.44		
$B^- \to a_0^0 K_0^{*-}$	9.28	5.42	5.07	2.84		
$B^- \to K_0^{*0} K_0^{*-}$	0.62	0.22	0.38	0.15	19	11

Numerical results and discussions

Table: The branching fractions(in units of 10^{-6})of $B_{u,d,s} \to M_1 M_2$ decays (ρ, ϕ)=(1,-55)

$B \to SS$	Class	CKM	S2	S1	$B \to PP$	Beneke	Exp
a_1 − *dominated*							
$B^- \to a_0^0 a_0^-$	T	1	24.83	12.06	$B^- \to \pi^0\pi^-$	6.0	5.5 ± 0.4
$\bar{B}_d^0 \to a_0^- a_0^+$	T	1	36.62	18.27	$\bar{B}_d^0 \to \pi^+\pi^-$	8.9	5.12 ± 0.19
$\bar{B}_s^0 \to a_0^- K_0^{*+}$	T	1	36.01	15.02	$\bar{B}_s^0 \to \pi^- K^+$	10.2	5.8 ± 0.7
$B^- \to a_0^0 K_0^{*-}$	T	λ^2	9.28	5.42	$B^- \to \pi^0 K^-$	11.1	12.9 ± 0.5
$\bar{B}_d^0 \to a_0^+ K_0^{*-}$	T	λ^2	11.31	7.92	$\bar{B}_d^0 \to \pi^+ K^-$	16.3	19.6 ± 0.5
$\bar{B}_s^0 \to K_0^{*-} K_0^{*+}$	T	λ^2	11.37	6.77	$\bar{B}_s^0 \to K^- K^+$	22.7	26.6 ± 2.2
a_2 − *dominated*							
$\bar{B}_s^0 \to a_0^0 K_0^{*0}$	C	1	0.55	0.27	$\bar{B}_s^0 \to \pi^0 K^0$	0.49	
$\bar{B}_d^0 \to a_0^0 a_0^0$	C	1	1.10	0.65	$\bar{B}_d^0 \to \pi^0\pi^0$	0.3	1.59 ± 0.26
$\bar{B}_d^0 \to a_0^0 \bar{K}_0^{*0}$	C	λ^2	3.90	3.39	$\bar{B}_d^0 \to \pi^0 \bar{K}^0$	7.0	9.9 ± 0.5
penguin-dominated							
$\bar{B}_s^0 \to \bar{K}_0^{*0} K_0^{*0}$	P	1	12.73	7.51	$\bar{B}_s^0 \to \bar{K}^0 K^0$	24.7	20.0 ± 6.0
$B^- \to a_0^- \bar{K}_0^{*0}$	P	1	13.60	9.41	$B^- \to \pi^- \bar{K}^0$	19.3	23.7 ± 0.8
$\bar{B}_d^0 \to K_0^{*0} \bar{K}_0^{*0}$	P	λ^2	0.59	0.21	$\bar{B}_d^0 \to K^0 \bar{K}^0$	1.35	1.21 ± 0.16
$B^- \to K_0^{*0} K_0^{*-}$	P	λ^2	0.57	0.15	$B^- \to K^0 K^-$	1.36	1.31 ± 0.17
ann-dominated							
$\bar{B}_s^0 \to a_0^0 a_0^0$	A	1	0.026	0.041	$\bar{B}_s^0 \to \pi^0\pi^0$	0.012	< 0.021
$\bar{B}_s^0 \to a_0^- a_0^+$	A	1	0.052	0.082	$\bar{B}_s^0 \to \pi^-\pi^+$	0.024	0.7 ± 0.1
$\bar{B}_d^0 \to K_0^{*-} K_0^{*+}$	A	1	0.01	0.01	$\bar{B}_d^0 \to K^- K^+$	0.013	0.078 ± 0.015

Numerical results and discussions

The $SU(3)$ flavor symmetry indicates

$$R_1 \equiv \frac{\Gamma_{B^- \to K_0^{*-} K_0^{*0}}}{\Gamma_{\bar{B}_d^0 \to \bar{K}_0^{*0} K_0^{*0}}} \approx 1\,, \qquad R_2 \equiv \frac{\Gamma_{B^- \to \bar{K}_0^{*0} a_0^-}}{\Gamma_{\bar{B}_d^0 \to K_0^{*-} a_0^+}} \approx 1\,, \tag{8}$$

$$R_3 \equiv \frac{\Gamma_{B^- \to \bar{K}_0^{*0} a_0^-}}{2\Gamma_{\bar{B}_d^0 \to \bar{K}_0^{*0} a_0^0}} \approx 1\,, \qquad R_3' \equiv \frac{\Gamma_{B^- \to \bar{K}_0^{*0} a_0^-}}{\Gamma_{\bar{B}_s^0 \to \bar{K}_0^{*0} K_0^{*0}}} \approx 1\,, \tag{9}$$

$$R_4 \equiv \frac{2\Gamma_{B^- \to K_0^{*-} a_0^0}}{\Gamma_{\bar{B}_d^0 \to K_0^{*-} a_0^+}} \approx 1\,, \qquad R_4' \equiv \frac{2\Gamma_{B^- \to K_0^{*-} a_0^0}}{\Gamma_{\bar{B}_s^0 \to K_0^{*-} K_0^{*+}}} \approx 1\,, \tag{10}$$

$$R_5 \equiv \frac{\Gamma_{\bar{B}_d^0 \to K_0^{*-} a_0^+}}{2\Gamma_{\bar{B}_d^0 \to \bar{K}_0^{*0} a_0^0}} \approx 1\,, \qquad R_6 \equiv \frac{\Gamma_{B^- \to \bar{K}_0^{*0} a_0^-}}{2\Gamma_{B^- \to K_0^{*-} a_0^0}} \approx 1\,, \tag{11}$$

$$R_7 \equiv \frac{\Gamma_{\bar{B}_d^0 \to a_0^0 a_0^0}}{2\Gamma_{\bar{B}_s^0 \to \bar{K}_0^{*0} a_0^0}} \approx 1\,, \qquad R_8 \equiv \frac{\Gamma_{\bar{B}_d^0 \to a_0^+ a_0^-}}{\Gamma_{B^- \to a_0^0 a_0^-}} \approx 1 \tag{12}$$

It is found in our calculation (S2) that

$$R_1 = 1.05\,, \quad R_2 = 1.23\,, \quad R_3 = 1.74\,, \quad R_3' = 1.07\,, \quad R_4 = 1.64\,, \quad R_4' = 1.63\,, \tag{13}$$

$$R_5 = 1.45\,, \quad R_6 = 0.73\,, \quad R_7 = 1.00\,, \quad R_8 = 1.47\,, \tag{14}$$

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Branching ratios and CP asymmetries of $B_{u/d/s} \to K_0^*(1430)\overline{K}_0^*(1430)$ decays in the pQCD approach

Xin Liu[1,2], Zhen-Jun Xiao[2] and Zhi-Tian Zou[3]

Introduction

QCD (pQCD) approach. Our predictions are the following: (1) the CP-averaged BRs for $B_{u/d/s} \to K_0^*(1430)\overline{K}_0^*(1430)$ decays in both scenarios vary in the range of $10^{-6} \sim 10^{-4}$ in the standard model; (2) the magnitudes of $A_{\rm CP}^{\rm dir}(B_u \to K_0^*(1430)^+\overline{K}_0^*(1430)^0)$ and $A_{\rm CP}^{\rm dir}(B_{d/s} \to K_0^*(1430)^+K_0^*(1430)^-)$ in scenario 1 are much larger than the corresponding magnitudes in scenario 2; (3) there are no direct CP violations in $B_{d/s} \to K_0^*(1430)^0\overline{K}_0^*(1430)^0$ decays in the standard model because of the involved pure penguin topology. *An experimental confirmation of* our pQCD predictions at the predicted level will favor the $q\bar{q}$ structure of the scalar $K_0^*(1430)$ and help us to understand its physical properties and the QCD dynamics involved.

- 使用PQCD的方法计算了$B_{u/d/s} \to K_0^*(1430)$的衰变分支比和CP
- 本篇文章对$B_{u/d/s} \to K_0^*(1430)$做出三个预言

Input

The values for scalar decay constants and Gegenbauer moments in the distribution amplitudes of K_0^* have been investigated at scale $\mu = 1\text{GeV}$ in scenarios S1 and S2 [9]:

$$\bar{f}_{K_0^*} = -0.300 \pm 0.030\ \text{GeV}, \quad B_1 = 0.58 \pm 0.07, \quad B_3 = -1.20 \pm 0.08\ (\text{S1}),$$
$$\bar{f}_{K_0^*} = 0.445 \pm 0.050\ \text{GeV}, \quad B_1 = -0.57 \pm 0.13, \quad B_3 = -0.42 \pm 0.22\ (\text{S2}). \tag{27}$$

$$F_{0,1}^{B\to K_0^*}(q^2=0) = \begin{cases} -0.34^{+0.04}_{-0.06}(\omega_b)^{+0.03}_{-0.04}(\bar{f}_S)^{+0.01}_{-0.03}(B_i^S) & (\text{S1}) \\ 0.63^{+0.10}_{-0.08}(\omega_b)^{+0.07}_{-0.07}(\bar{f}_S)^{+0.06}_{-0.06}(B_i^S) & (\text{S2}), \end{cases}$$

$$F_{0,1}^{B_s\to \overline{K}_0^*}(q^2=0) = \begin{cases} -0.31^{+0.05}_{-0.05}(\omega_{bs})^{+0.03}_{-0.03}(\bar{f}_S)^{+0.01}_{-0.01}(B_i^S) & (\text{S1}) \\ 0.57^{+0.09}_{-0.08}(\omega_{bs})^{+0.06}_{-0.07}(\bar{f}_S)^{+0.05}_{-0.06}(B_i^S) & (\text{S2}), \end{cases}$$

$$Br(B_u \to K_0^{*+}\overline{K}_0^{*0}) \approx \begin{cases} 1.1^{+0.1}_{-0.2}(\omega_b)^{+0.5}_{-0.4}(\bar{f}_S)^{+0.1}_{-0.2}(B_i^S) \times 10^{-5} & (S1) \\ 1.9^{+0.2}_{-0.1}(\omega_b)^{+1.1}_{-0.7}(\bar{f}_S)^{+1.3}_{-0.9}(B_i^S) \times 10^{-5} & (S2), \end{cases}$$

$$Br(B_d \to K_0^{*0}\overline{K}_0^{*0}) \approx \begin{cases} 1.1^{+0.2}_{-0.2}(\omega_b)^{+0.6}_{-0.4}(\bar{f}_S)^{+0.2}_{-0.1}(B_i^S) \times 10^{-5} & (S1) \\ 2.0^{+0.0}_{-0.1}(\omega_b)^{+1.0}_{-0.8}(\bar{f}_S)^{+1.7}_{-1.2}(B_i^S) \times 10^{-5} & (S2), \end{cases}$$

$$Br(B_d \to K_0^{*+}K_0^{*-}) \approx \begin{cases} 3.2^{+0.0}_{-0.1}(\omega_b)^{+1.6}_{-1.1}(\bar{f}_S)^{+1.0}_{-0.8}(B_i^S) \times 10^{-6} & (S1) \\ 2.2^{+0.4}_{-0.4}(\omega_b)^{+1.1}_{-0.8}(\bar{f}_S)^{+1.8}_{-1.2}(B_i^S) \times 10^{-6} & (S2); \end{cases}$$

$$Br(B_s \to K_0^{*0}\overline{K}_0^{*0}) \approx \begin{cases} 2.5^{+0.6}_{-0.5}(\omega_{bs})^{+1.1}_{-0.9}(\bar{f}_S)^{+0.4}_{-0.4}(B_i^S) \times 10^{-4} & (S1) \\ 5.4^{+0.1}_{-0.2}(\omega_{bs})^{+2.8}_{-2.1}(\bar{f}_S)^{+4.8}_{-3.3}(B_i^S) \times 10^{-4} & (S2), \end{cases}$$

$$Br(B_s \to K_0^{*+}K_0^{*-}) \approx \begin{cases} 2.3^{+0.5}_{-0.4}(\omega_{bs})^{+1.1}_{-0.8}(\bar{f}_S)^{+0.4}_{-0.4}(B_i^S) \times 10^{-4} & (S1) \\ 5.2^{+0.2}_{-0.2}(\omega_{bs})^{+2.8}_{-2.0}(\bar{f}_S)^{+4.6}_{-3.1}(B_i^S) \times 10^{-4} & (S2). \end{cases}$$

Table: The branching fractions (in units of 10^{-6}) of $B_{u,d,s} \to M_1 M_2$ decays .

	$(\rho_{i,f}, \phi_{i,f}) = (1, -55)$		$(\rho_i, \phi_i) = (2.97, -105)$ $(\rho_f, \phi_f) = (2.8, 165)$		PQCD (LiuXin)		
Decay modes	S2	S1	S2	S1	S2	S1	Exp
$\bar{B}_s^0 \to a_0^- a_0^+$	0.05	0.08	0.29	0.64	3.55	5.63	
$\bar{B}_s^0 \to K_0^{*-} K_0^{*+}$	11.37	6.77	4.90	4.94	520	230	
$\bar{B}_s^0 \to \bar{K}_0^{*0} K_0^{*0}$	12.73	7.51	4.78	3.66	540	250	
$\bar{B}_d^0 \to K_0^{*-} K_0^{*+}$	0.01	0.01	0.06	0.07	2.2	3.2	
$\bar{B}_d^0 \to K_0^{*0} \bar{K}_0^{*0}$	0.59	0.21	0.27	0.12	20	11	$3.21^{+3.70}_{-3.67}$
$B^- \to K_0^{*0} K_0^{*-}$	0.62	0.22	0.38	0.15	19	11	

谢谢！