Nonet symmetry and two-body decays of charmed mesons

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The decay of charmed mesons into pseudoscalar (P) and vector (V) mesons is studied in the context of nonet symmetry. We have found that it is badly broken in the PP channels and in the P sector of the PV channels as expected from the nonideal mixing of the η and the η'. In the VV channels it is also found that nonet symmetry does not describe the data well. We have found that this discrepancy cannot be attributed entirely to SU(3) breaking at the usual level of 20–30 %. At least one, or both, of nonet and SU(3) symmetries must be very badly broken. The possibility of resolving the problem in the future is also discussed.

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I. INTRODUCTION

The original motivation for nonet symmetry [1] in flavor SU(3) is the near *ideal* mixing of the ω and ϕ mesons, and the extension to the pseudoscalar sector goes back to one of the original studies of charmed meson decays [2]. In this paper, we investigate the validity of nonet symmetry in Cabibbo-allowed two-body decays of charmed mesons (D) into pseudoscalar (P) and vector (V) mesons.

Flavor SU(3) has been a very powerful tool for the study of strange particle decays, but there is a problem when it is applied to charm decays. The ratio of partial widths of the two Cabibbo-suppressed modes

$$R=\frac{B(D^0\to K^+K^-)}{B(D^0\to\pi^+\pi^-)} \tag{1}$$

is measured to be roughly 3 while SU(3) predicts a value close to 1, indicating large symmetry-breaking effects. However, we have pointed out elsewhere [3] that it is possible for SU(3) breaking to be confined to the Cabibbo-suppressed sector and to not affect the allowed decays at all.

In terms of SU(3) irreducible representations, the Hamiltonian for charm decay transforms as $\mathbf{15}^*+\mathbf{6}$. If the SU(3)-breaking term transforms as an octet [4], the Hamiltonian will pick up many new representations [3,5]:

$$\begin{aligned} H\to H&+\mathbf{42}^*+\mathbf{24}_1^*+\mathbf{24}_2^*+\mathbf{15}_S^* \\ &+\mathbf{15}_1^*+\mathbf{15}_2^*+\mathbf{15}_3^*+\mathbf{6}_1+\mathbf{6}_2+\mathbf{3}_2^*+\mathbf{3}_2^* . \end{aligned} \tag{2}$$

While all of these affect the Cabibbo-suppressed modes, only the $\mathbf{42}$ and the $\mathbf{24}^*$'s contribute to Cabibbo-allowed decays. We have shown in [3] that all present data in the PP channels, including (1), can be accounted for by introducing just a $\mathbf{3}^*$. Therefore, we will work under the general assumption that SU(3) is a useful symmetry for Cabibbo-allowed decays.

In an earlier paper [6], one of us has already shown that nonet symmetry does not work in $D\to PP$. We repeat the analysis here in light of more recent data and we also show that it does not work for $D\to PV$, possibly through a breakdown in the P sector. As a further test, we will look at $D\to VV$ where it is expected to work. However, we find that it does not. An alternative explanation using the breakdown of SU(3) symmetry is also explored. The present status of experimental data does not yet allow us to draw any definite conclusions.

The discussion of charm decay in the context of SU(3) [7] and nonet symmetry [8] has been treated in great detail in the literature. Here, we adopt the notation of Ref. [6]: The incorporation of the singlet into the octet to form the nonet does not alter the Clebsch-Gordan series of $\mathbf{8}\otimes\mathbf{8}=\mathbf{27}+\mathbf{10}+\mathbf{10}^*+\mathbf{8}+\mathbf{8}+\mathbf{1}$. We will label the reduced matrix elements obtained from the $\mathbf{27}$ as T, those from the $\mathbf{10}$ and $\mathbf{10}^*$ as D and those from the symmetric and antisymmetric combinations of the two $\mathbf{8}$'s as S and A, respectively. Finally, the overall representation will be denoted by a subscript so that T_{15} would be the reduced matrix element of the $\mathbf{15}$ obtained from $\mathbf{27}\otimes\mathbf{3}$.

The D's and the A's are antisymmetric under the exchange of the final-state mesons so that they do not contribute to PP and VV channels. It is convenient to introduce the combinations $S_\pm=S_{15}\pm S_6$ and $A_\pm=A_{15}\pm A_6$ because each of these occurs only in the decays of either D^0 or D_s but not both. The decay amplitudes are summarized in Tables I–III along with the relevant phase space factors and experimentally measured branching ratios.

When nonet symmetry is broken, amplitudes involving the singlets are no longer related to those involving only members of the octets. To parametrize the extent of the breaking, we keep the original amplitudes under nonet symmetry and introduce a new amplitude B for each channel involving a singlet. Two such amplitudes are used in each of Tables I and III for the discussion of the PP and VV channels.

For computational purposes, we define all amplitudes in terms of branching ratios expressed in percent by the relation

$$B(D_i\to XY)=\frac{|A(D_i\to XY)|^2\times\text{kinematical factor}}{\Gamma(D_i)/\Gamma(D^0)} , \tag{3}$$

where the kinematical factor takes into account effects of phase space as well as the polarization of vector mesons. To allow for elastic final-state interactions, we have taken all amplitudes to be complex. To solve for both the real and imaginary parts of one, we will need two branching ratios. Also, because of the quadratic nature of Eq. (3), there will in general be a twofold ambiguity in each solution.

Error analysis here is rather complicated. To simplify the discussion, uncertainty in all masses and lifetimes are ignored. We also treat the uncertainties in all measured branching ratios as independent, but will try to keep track of their propagation into various derived quantities correctly. In cases where a common normalization is used, such as in D_s decays, the ratios instead of the absolute branching ratios will be treated as independent. All data except as indicated otherwise are taken from Ref. [9].

We will discuss the decay of charmed mesons into *PP*, *PV*, and *VV* channels separately in Secs. II–IV. Section V will be devoted to the study of possible SU(3) breaking in the *VV* channels. We conclude with a brief summary in Sec. VI.

II. $D \to PP$

Table I summarizes all relevent information about the *PP* channels. Almost all Cabibbo-allowed modes are very well measured, especially in the D^0 sector. Even in the presence of the nonet breaking amplitude B_+, we have enough data to solve for all amplitudes. Without loss of generality, we will take T_{15} to be real and positive and the imaginary part of S_+ to be also positive. The D^+ branching ratio gives us directly T_{15}; S_+ can then be found from modes 2 and 3. To solve for B_+, we need to express the η_8, η_1 amplitudes in terms of η, η'. We do this by using a pseudoscalar mixing angle [11] of $-20°$ and the solutions are

$$\begin{aligned} &5T_{15} = 1.10 \pm 0.08 \,, \\ &S_+ = (0.04 \pm 0.24) + i(1.92 \pm 0.06) \,, \\ &B_+ = \begin{cases} +(1.92 \pm 0.23) - i(1.56 \pm 0.49) \,, \\ -(1.86 \pm 0.36) - i(2.72 \pm 0.41) \,. \end{cases} \end{aligned} \tag{4}$$

The large size of B_+ clearly indicates that nonet symmetry in this sector of charm decay is badly broken.

In the D_s sector there are two new amplitudes S_- and B_-, but only three extra branching ratios. We do not have enough information to solve for everything, but there exist triangular sum rules which impose constraints on the amplitudes.

To simplify the discussion, we set $B_- = 0$ and see if this would lead to any contradictions. Table I gives us the relations

$$\sqrt{3} A(\pi\eta_1) - \sqrt{6} A(\pi\eta_8) = 6T_{15} \,, \tag{5}$$

$$\tfrac{5}{2}\sqrt{3} A(\pi\eta_1) - \sqrt{6} A(\pi\eta_8) = 3A(K^+\bar{K}^0) \,. \tag{6}$$

Putting in the pseudoscalar mixing angle θ to convert $\eta_{1,8}$ into η, η', we obtain, from Eq. (5),

$$\begin{array}{lcccc} & (\cos\theta - \sqrt{2}\sin\theta) A_{\pi\eta'} & - & (\sqrt{2}\cos\theta + \sin\theta) A_{\pi\eta} & = 2\sqrt{3} T_{15} \\ \theta = -20°: & 3.22 \pm 0.54 & & 1.26 \pm 0.17 & 0.73 \pm 0.06 \\ \theta = -10°: & 2.78 \pm 0.47 & & 1.55 \pm 0.21 & \end{array} \tag{7}$$

The number under each term is the magnitude of that amplitude evaluated with the mixing angle indicated. For $\theta = -20°$, we have $3.22 - 1.26 = 1.96 > 0.73$. Even if we take into account the errors in each term, there is no choice of phase in which the three amplitudes can form a closed triangle. This is strong evidence that B_- has to be nonzero. For $\theta = -10°$, the three amplitudes are barely consistent with $B_- = 0$ if the errors are stretched to their limits.

The corresponding results for Eq. (6) are

$$\begin{array}{lcccc} & [\cos\theta - (\sqrt{8}/5)\sin\theta] A_{\pi\eta'} & - & [(\sqrt{8}/5)\cos\theta + \sin\theta] A_{\pi\eta} & = \tfrac{2}{5}\sqrt{3} A_{KK} \\ \theta = -20°: & 1.59 \pm 0.23 & & 0.15 \pm 0.02 & 0.77 \pm 0.06 \\ \theta = -10°: & 1.52 \pm 0.22 & & 0.30 \pm 0.03 & \end{array} \tag{8}$$

TABLE I. Amplitudes and branching ratios for $D \to PP$.

	Mode	Amplitude	Kinematical factor	Branching ratio (%)
1.	$D^+ \to \bar{K}^0 \pi^+$	$5T_{15}$	0.9203	2.6 ± 0.4
2.	$D^0 \to K^- \pi^+$	$2T_{15} + S_+$	0.9235	3.60 ± 0.21
3.	$D^0 \to \bar{K}^0 \pi^0$	$1/\sqrt{2}(3T_{15} - S_+)$	0.9227	1.86 ± 0.20[a]
4.[b]	$D^0 \to \bar{K}^0 \eta_8$	$1/\sqrt{6}(3T_{15} - S_+)$	0.8273	1.12 ± 0.22[a]
5.[b]	$D^0 \to \bar{K}^0 \eta_1$	$2/\sqrt{3}(S_+ + B_+)$	0.6059	2.79 ± 0.42[a]
6.	$D_s \to \bar{K}^0 K^+$	$2T_{15} + S_-$	0.8182	$(1.01 \pm 0.16) B_{\phi\pi^+}$
7.[b]	$D_s \to \eta_8 \pi^+$	$\sqrt{2/3}(S_- - 3T_{15})$	0.8679	$(0.54 \pm 0.11) B_{\phi\pi^+}$
8.[b]	$D_s \to \eta_1 \pi^+$	$2/\sqrt{3}(S_- + B_-)$	0.7153	$(1.4 \pm 0.4) B_{\phi\pi^+}$

[a]Combined result of CLEO, ARGUS, and MARK III data, taken from Ref. [10].

[b]Kinematical factors and branching ratios listed for η_8, η_1 modes are those for η, η' modes, respectively.

Here, the common factor $\sqrt{B_{\phi\pi^+}\Gamma(D_s)/\Gamma(D^0)}$ in the three amplitudes has been factored out so that the listed errors can be treated as more or less independent. If we take the difference between the two terms on the left, we obtain 1.44 ± 0.23 for $\theta=-20°$ and 1.21 ± 0.22 for $\theta=-10°$. To form closed triangles, these have to be less than 0.77 ± 0.06, which is not quite true. Thus we have shown once again that prediction from nonet symmetry does not agree with data.

III. $D\to PV$

The sheer number of independent amplitudes in the PV channels make the analysis much more complicated. Because of the abundance of data, all quantities in the D^0 modes can be solved in terms of the relative phase between the two D^+ amplitudes. However, as mentioned earlier, there are discrete ambiguities in the solutions, and this makes precise predictions very difficult. So far, we have found no inconsistency between the data and amplitudes shown in Table II. We will see below that this is not the case with D_s decays.

The experimental situation in the D_s modes is somewhat less developed, but there are three sum rules that we can use. We will try to determine the effect they have on the amplitude S_-. First of all, from the two KK^* channels we have

$$A(K^+\bar{K}^{*0})+A(\bar{K}^0K^{*+}) = 2S_- + \tfrac{2}{5}A(\bar{K}^0\rho^+)+\tfrac{2}{5}A(\pi^+\bar{K}^{*0}) \ . \quad (9)$$

Putting in numerical values for the amplitudes gives

$$|S_-|\le 3.23\pm0.28 \ . \quad (10)$$

From the $\omega\pi^+$ and $\phi\pi^+$ decays, where the ω mode has only an upper limit, we get

$$2S_- = \sqrt{2}A(\pi^+\omega)+A(\pi^+\phi) \ ,$$
$$0.56\pm0.05\le|S_-|\le 2.14\pm0.19 \ . \quad (11)$$

Finally, expressing η_1 in terms of η,η' gives

$$\frac{2}{\sqrt{3}}S_- = A(\eta'\rho^+)\cos\theta - A(\eta\rho^+)\sin\theta \ ,$$
$$\theta=-20°:\ 4.62\pm0.76\le|S_-|\le 6.56\pm0.86 \ , \quad (12)$$
$$\theta=-10°:\ 5.37\pm0.81\le|S_-|\le 6.35\pm0.87 \ .$$

Relations (10) and (11) are compatible with each other but not with (12). A natural explanation would be that there is a large nonet symmetry breaking in the η-η' sector but none in the ϕ-ω sector.

To test the idea of nonet symmetry in the ϕ-ω sector we look at pure VV decays in the next section.

IV. $D\to VV$

In VV channels, partial waves with $L=0,1,2$ can all contribute. Since the available phase-space is generally small and the phase-space factor depends on the center-of-mass momentum as p^{2L+1}, s waves tend to dominate. This is well supported by data of the ρK^* modes [9,12]. Keeping only s waves makes the SU(3) amplitudes of the VV modes look very similar to those of the PP modes with the exception that $D^0\to\phi\bar{K}^{*0}$ is kinematically forbidden. This means that we will not have enough information to determine both the phase and modulus of the B_+ amplitude.

Table III summarizes the situations. It is obvious that we can still determine T_{15} and S_+ from the three ρK^* modes. By assuming B_+ to be zero, we can make a prediction for the ωK^* branching ratio:

$$B(D^0\to\omega\bar{K}^{*0})=(2.5\pm1.0)\% \ . \quad (13)$$

This is barely compatible with the experimental limit of $<1.5\%$, and we are close to being able to claim a nonzero value for B_+. We now turn to the D_s modes.

TABLE II. Amplitudes and branching ratios for $D\to PV$.

	Mode	Amplitude	Kinematical factor	Branching ratio (%)
1.	$D^+\to\bar{K}^0\rho^+$	$5T_{15}+3D_6$	0.5725	6.6 ± 1.7
2.	$D^+\to\pi^+\bar{K}^{*0}$	$5T_{15}-3D_6$	0.4812	1.9 ± 0.7
3.	$D^0\to\pi^+K^{*-}$	$2T_{15}+S_++A_+-D_6-D_{15}$	0.4840	4.5 ± 0.6
4.	$D^0\to\pi^0\bar{K}^{*0}$	$1/\sqrt{2}(3T_{15}-S_+-A_+-2D_6+D_{15})$	0.4762	2.1 ± 1.0
5.	$D^0\to K^-\rho^+$	$2T_{15}+S_+-A_++D_6+D_{15}$	0.5684	7.3 ± 1.1
6.	$D^0\to\bar{K}^0\rho^0$	$1/\sqrt{2}(3T_{15}-S_++A_++2D_6-D_{15})$	0.5642	0.61 ± 0.30
7.	$D^0\to\bar{K}^0\omega$	$1/\sqrt{2}(T_{15}+S_+-A_+-D_{15})$	0.5277	2.5 ± 0.5
8.	$D^0\to\bar{K}^0\phi$	$-T_{15}+S_++A_++D_{15}$	0.1454	0.88 ± 0.12
9.[a]	$D^0\to\eta_8\bar{K}^{*0}$	$1/\sqrt{6}(3T_{15}-S_++3A_++3D_{15})$	0.2591	2.1 ± 1.2
10.[a]	$D^0\to\eta_1\bar{K}^{*0}$	$2S_+/\sqrt{3}$	0.0014	
11.	$D_s\to K^+\bar{K}^{*0}$	$2T_{15}+S_--A_--D_6+D_{15}$	0.4248	$(0.95\pm0.10)B_{\phi\pi^+}$
12.	$D_s\to\bar{K}^0K^{*+}$	$2T_{15}+S_-+A_-+D_6-D_{15}$	0.4303	$(1.20\pm0.25)B_{\phi\pi^+}$
13.	$D_s\to\pi^+\rho^0$	$+1/\sqrt{2}(2A_--D_6+D_{15})$	1.0306	$<0.08B_{\phi\pi^+}$ C.L. $=90\%$
14.	$D_s\to\pi^0\rho^+$	$-1/\sqrt{2}(2A_--D_6+D_{15})$	1.0323	
15.	$D_s\to\pi^+\omega$	$1/\sqrt{2}(-2T_{15}+2S_-+D_6+D_{15})$	0.9752	$<0.5B_{\phi\pi^+}$ C.L. $=90\%$
16.	$D_s\to\pi^+\phi$	$2T_{15}-D_6-D_{15}$	0.3724	2.8 ± 0.5
17.[a]	$D_s\to\eta_8\rho^+$	$1/\sqrt{6}(-6T_{15}+2S_--3D_6-3D_{15})$	0.6986	$(2.86\pm0.54)B_{\phi\pi^+}$
18.[a]	$D_s\to\eta_1\rho^+$	$2S_-/\sqrt{3}$	0.1906	$(3.44\pm0.77)B_{\phi\pi^+}$

[a]Kinematical factors and branching ratios listed for η_8,η_1 modes are those for η,η' modes, respectively.

TABLE III. Amplitudes and branching ratios for $D \to VV$.

	Mode	Amplitude	Kinematical factor	Branching ratio (%)
1.	$D^+ \to \bar{K}^{*0}\rho^+$	$5T_{15}$	1.5971	$4.1^{+1.5}_{-1.2}$
2.	$D^0 \to K^{*-}\rho^+$	$2T_{15}+S_+$	1.6015	6.2 ± 2.5
3.	$D^0 \to \bar{K}^{*0}\rho^0$	$1/\sqrt{2}(3T_{15}-S_+)$	1.5795	1.5 ± 0.6
4.	$D^0 \to \bar{K}^{*0}\omega$	$1/\sqrt{2}(T_{15}+S_+ +2B_+)$	1.5100	<1.5 C.L.=90%
5.	$D^0 \to \bar{K}^{*0}\phi$	$-T_{15}+S_+ +B_+$	0	
6.	$D_s \to \bar{K}^{*0}K^{*+}$	$2T_{15}+S_-$	1.3582	$(1.8\pm 0.5)B_{\phi\pi^+}$
7.	$D_s \to \omega\rho^+$	$\sqrt{2}(-T_{15}+S_- +B_-)$	2.4666	
8.	$D_s \to \phi\rho^+$	$2T_{15}+B_-$	1.3514	$(1.86^{+0.39}_{-0.48})B_{\phi\pi^+}$

In the absence of nonet symmetry breaking, Table III tells us that A_1, the D^+ amplitude, would be 2.5 times as large as A_8, the $\phi\rho^+$ amplitude. Phase spaces for the two cases are comparable; with the lifetime of the D^+ being 2.5 times as large as that of the D_s, this translates directly into a factor of more than 15 for the branching ratios. This is in serious contradiction with data ($B_1/B_8 \approx 0.8\pm 0.4$) and we are left with the disturbing fact that B_- is indeed large—something that has not been borne out by the PV analysis. To be more specific, we can write

$$\begin{aligned} B_- &= A_1 - \tfrac{2}{5}A_8 \\ &\geq |A_1| - \tfrac{2}{5}|A_8| \\ &= 1.5\pm 0.3 \ . \end{aligned} \tag{14}$$

Our reluctance to give up nonet symmetry for the vector mesons leads us to investigate the possibility that a small SU(3) breaking may be responsible for the discrepancy.

V. SU(3) BREAKING

As pointed out earlier, SU(3) breaking by an octet leads to three new representations: one **42** and two **24***'s. For PP and VV modes, the two **24***'s are identical so that there are only two new amplitudes, both coming from the **27** of **8**⊗**8**. They appear in Table IV as T_{42} and T_{24}.

In the wake of SU(3) breaking, the situation has become much more complicated, but two things remain unchanged. The first is the isospin relation of the three $K^*\rho$ amplitudes; isospin is obviously still a good symmetry by design. The second is that the two amplitudes involving the singlet ω_1 are unaffected. Unfortunately, one of these is connected to the kinematically forbidden ϕK^* mode. The other one also gives us the relation

$$5B_- = \sqrt{2}A_{\omega\rho} + 3A_{\phi\rho} - 2A_{KK} \ . \tag{15}$$

This relation holds regardless of whether or not there is SU(3) breaking. If we can show that the three amplitudes on the right-hand side do not form a closed triangle, then we definitely have nonet symmetry breaking; the contrary, unfortunately, is not true. Presently, there is no measurement of the $\omega\rho^+$ branching ratio; we can always let $B_- = 0$ and look forward to its value allowable under nonet symmetry:

$$\sqrt{2}|A_{\omega\rho}| \geq ||3A_{\phi\rho}| - |2A_{KK}|| \tag{16}$$

gives

$$\frac{B(D_s \to \omega\rho^+)}{B(D_s \to \phi\pi^+)} \geq 1.8^{+1.5}_{-1.7} \ . \tag{17}$$

With the improvement of data, this may become a very important constraint. If the $\phi\rho^+$ and $K^+\bar{K}^0$ branching ratios keep their present central values, but instead of the present value of roughly ± 0.5 as shown in Table III, the errors shrink down to, e.g., ± 0.2, the ratio in Eq. (17) would become $\geq 1.8\pm 0.7$. This would limit the $\omega\rho^+$ rates to be at least as large as the $\phi\pi^+$ rate. Returning to the relation between A_1 and A_8 and judging from the expressions in Table IV, it is inevitable that at least one of B_-, T_{24}, and T_{42} must be large.

Relation (16) can also be used for the PP channels. The corresponding relation for the pseudoscalar case is exactly relation (8) we obtained earlier. Therefore in the case of $D \to PP$ we have effectively shown that nonet symmetry is not obeyed regardless of whether or not there is SU(3) breaking.

TABLE IV. Amplitudes for $D \to VV$ with flavor symmetry breakings.

	Mode	Amplitude
1.	$D^+ \to \bar{K}^{*0}\rho^+$	$5T_{15}+5T_{24}-T_{42}$
2.	$D^0 \to K^{*-}\rho^+$	$2T_{15}+S_+ -T_{24}-T_{42}$
3.	$D^0 \to \bar{K}^{*0}\rho^0$	$1/\sqrt{2}(3T_{15}-S_+ +6T_{24})$
4.	$D^0 \to \bar{K}^{*0}\omega$	$1/\sqrt{2}(T_{15}+S_+ -8T_{24}-2T_{42}+2B_+)$
5.	$D^0 \to \bar{K}^{*0}\phi$	$-T_{15}+S_+ +8T_{24}+2T_{42}+B_+$
6.	$D_s \to \bar{K}^{*0}K^{*+}$	$2T_{15}+S_- -4T_{24}+2T_{42}$
7.	$D_s \to \omega\rho^+$	$\sqrt{2}(-T_{15}+S_- +2T_{24}-T_{42}+B_-)$
8.	$D_s \to \phi\rho^+$	$2T_{15}-4T_{24}+2T_{42}+B_-$
4′.	$D^0 \to \bar{K}^{*0}\omega_8$	$1/\sqrt{6}(3T_{15}-S_+ -24T_{24}-6T_{42})$
5′.	$D^0 \to \bar{K}^{*0}\omega_1$	$2/\sqrt{3}(S_+ +B_+)$
7′.	$D_s \to \omega_8\,\rho^+$	$2/\sqrt{6}(-3T_{15}+S_- +6T_{24}-3T_{42})$
8′.	$D_s \to \omega_1\,\rho^+$	$2/\sqrt{3}(S_- +B_-)$

VI. SUMMARY

We have shown in Sec. II that nonet symmetry is badly broken in the PP channels. Even with the help of SU(3) breaking, one cannot evade this inevitable consequence. The situation with the PV channels is less clear. It seems that nonet symmetry may still be good in the vector sector but not in the pseudoscalar sector. Also, we have not found any evidence for SU(3) breaking there. Compared with these two cases, the situation in the VV channels is much more confusing. First of all, we have shown by comparing $D^+ \to \bar{K}^{*0}\rho^+$ and $D_s \to \phi\rho^+$ that at least one of the three symmetry-breaking amplitudes must be large. Second, we have not been able to rule out the possibility of having large SU(3) breaking effects. In fact, it will not be possible for us to completely rule out the breakdown of either SU(3) or nonet symmetry by studying Cabibbo-allowed decays alone because there are simply too many free parameters. However, if nature cooperates, we may be able to confirm explicitly the breakdown of nonet symmetry in the vector sector via the $D_s \to \omega\rho^+$ decay.

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