LETTER TO THE EDITOR

A MODEL-INDEPENDENT APPROACH TO THE SUPPRESSION PROBLEMS OF THE DECAYS ψ (4.03) $\to D\bar{D}$ AND ψ (4.42) $\to D\bar{D}$, $F\bar{F}$

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It is well known that the charmonium model cannot offer any explanation for the surprisingly strong suppressions of the decays ψ (4.03) $\to D\bar{D}$ and ψ (4.42) $\to D\bar{D}$, $F\bar{F}$. In the literature various models have been suggested in order to account for the suppression of the $D\bar{D}$ mode in ψ (4.03)-decay but these models are unable to explain the suppressions of the $D\bar{D}$ and $F\bar{F}$ modes in ψ (4.42)-decay. This note presents a model-independent explanation for the suppressions of the decays concerned.

The well advertized charmonium model [1–4] seems to be in difficulty for the charmonium states which are appreciably above the OZI-threshold. In fact, the decays of the "unbound" resonances ψ (4.03) and ψ (4.42) have posed a serious problem for the charmonium model within the framework of which there are no provisions for the suppressions of the decays ψ (4.03) $\to D\bar{D}$ and ψ (4.42) $\to D\bar{D}$, $F\bar{F}$. The suppressions of these decays are indeed surprising. This is because the OZI-allowed modes [4] for ψ (4.03)-decay are the $D\bar{D}$, $D\bar{D}^*$ and $D^*\bar{D}^*$ and the same for ψ (4.42)-decay are the $D\bar{D}$, $F\bar{F}$, $D\bar{D}^*$, $D^*\bar{D}^*$, $F\bar{F}^*$ and $F^*\bar{F}^*$. All these decays, being OZI-allowed, can occur through the "connected" diagrams via intermediate "soft" gluons. Since all other factors are the same for these decays, therefore, the phase space factor is expected to have an important role in determining the relative dominance of the modes of the particles concerned. From phase space considerations, therefore, the decays ψ (4.03) $\to D\bar{D}$ and ψ (4.42) $\to D\bar{D}$, $F\bar{F}$ are expected to be dominant ones. Contrary to these expectations, the decays ψ (4.03) $\to D\bar{D}$ have been observed to be strongly suppressed [4] compared to the decays ψ (4.03) $\to D^*\bar{D}^*$. Also the decays ψ (4.42) $\to D\bar{D}$, $F\bar{F}$ have not been seen [4] but the decays ψ (4.42) $\to F\bar{F}^*$ have been observed [4]. In this connection we may also note that all the selection rules appropriate for strong decays completely fail to explain the suppressions of the decays concerned.

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It is also interesting to note that to tackle the suppression problem of the decays ψ (4.03) → → $D\bar{D}$ various models, given in Ref. [4], have been proposed. Needless to mention that none of these models can account for the suppressions of the decays ψ (4.42) → $D\bar{D}$, $F\bar{F}$. The purpose of this note is to describe a model-independent approach to the suppression problems of the decays under investigations. The method concerned has been described in a compact form in a recent paper [5]. This method utilizes the pseudo-dimension rule [5–9] described briefly below.

The pseudo-dimension rule reads: All the allowed decays of an unstable particle must be governed by *one and only one* of the following two constraints

$$d_u \geqslant D, \tag{1a}$$

$$d_u \leqslant D, \tag{1b}$$

where d_u is the magnitude of the pseudo-dimension of the field of the unstable particle and D is the sum of the magnitudes of the fields of the particles constituting a decay mode for the unstable particle concerned. The magnitude of the pseudo-dimension, denoted by d, of a free field carrying the actual spin J is given by [5–9]

$$d = 3J \text{ for } J \neq 0, \tag{2a}$$

$$d = 1 \quad \text{for } J = 0, \tag{2b}$$

$$d = 2 \quad \text{for the photon.} \tag{2c}$$

To exemplify how the pseudo-dimension rule explains [6–10] the suppressions of the otherwise theoretically expected decay modes of the unstable particles, we consider $\omega(783)$-decay. For the observed [10] decays $\omega(783) \to 2\pi, 3\pi, \pi^0\gamma, e^+e^-$ we have for the ω (which is a $J = 1$ particle), $d_u = 3$ which follows from Eq. (2a) and for the 2π mode $D = d_\pi + d_\pi = 1+1 = 2$ as $d_\pi = 1$ which is evident from Eq. (2b); for $\pi^0\gamma$ mode, $D = d_\pi + d_\gamma = 1+2 = 3$ since $d_\gamma = 2$ which follows from Eq. (2c) and for the e^+e^- mode $D = d_{e+} + d_{e-} = 3/2+3/2 = 3$ as $d = 3/2$ for a spin $-\frac{1}{2}$ particle as implied by Eq. (2a). Clearly, then, the observed decays $\omega(d_u = 3) \to 2\pi(D = 2)$, $3\pi(D = 3)$, $\pi^0\gamma(D = 3)$, e^+e^- $(D = 3)$ reveal that the constraint appropriate for ω-decay is $d_u \geqslant D$ which must be satisfied by all other theoretically expected modes in order that they are not forbidden (and as such unsuppressed) by the pseudo-dimension rule. This is so because according to the pseudo-dimension rule *all* the allowed decays of a given unstable particle must be controlled by one and the same constraint. It is interesting to note that the constraint $d_u \geqslant D$, which is found to hold in the observed decays of the $\omega(783)$, is not satisfied by the theoretically expected modes $\pi^+\pi^-\gamma$ $(D = 4)$, $\pi^0\pi^0\gamma$ $(D = 4)$, $\pi^0\mu^+\mu^-$ $(D = 4)$, 3γ $(D = 6)$ as $d_u = 3$ for the $\omega(783)$. These modes, needless to mention, have not been seen [10]. We now consider the performance of the selection rule under considerations in the decays of the $\psi(3100)$ and $\psi'(3685)$. The observed [10] decays $\psi(3100, d_u = 3) \to e^+e^-$ $(D = 3)$, $\mu^+\mu^-$ $(D = 3)$, 4π $(D = 4)$, 5π $(D = 5)$, 6π $(D = 6)$, 7π $(D = 7)$ and $\psi'(3685, d_u = 3) \to e^+e^-$ $(D = 3)$, $\mu^+\mu^-$ $(D = 3)$, $\psi\eta$ $(D = 4)$, $\psi\pi\pi$ $(D = 5)$, ... suggest that the decays of both the ψ and ψ' are governed by the constraint $d_u \leqslant D$ which is, however, not satisfied by the modes $\pi^+\pi^-$ $(D = 2)$, K^+K^-

($D = 2$). Therefore, according to the selection rule concerned, the decays $\psi, \psi' \to \pi^+\pi^-$, K^+K^- are forbidden and as a consequence these decays should be suppressed [5]. This is in conformity with the experimental facts [10]. It is gratifying to note that the suppressions of the decays like $\psi, \psi' \to \pi\pi$, $K\bar{K}$ and $\varrho(1250) \to 2\pi$, $\varrho(1600) \to 2\pi$ are not understood in terms of any known selection rule except the pseudo-dimension rule [5–9]. We have illustrated our method considering a few examples. Many such examples have been discussed in previous papers [5–9].

It is evident from the observed [4] decays ψ (4.03, $d_u = 3$) $\to e^+e^-$ ($D = 3$), D(1865) $\bar{D}^*(2010)$($D = 1+3 = 4$), $D^*(2010)\bar{D}^*(2010)$($D = 3+3 = 6$) and ψ(4.42, $d_u = 3$) $\to e^+e^-$ ($D = 3$), F(2030)$\bar{F}^*(2140)$($D = 1+3 = 4$) that for the decays of both the ψ(4.03) and ψ(4.42) the appropriate constraint is $d_u \leqslant D$ which is clearly not satisfied by the D(1865) $\bar{D}$(1865) ($D = 2$) mode for ψ(4.03)-decay and the D(1865)$\bar{D}$(1865) ($D = 2$), F(2030) $\bar{F}$(2030) ($D = 2$) modes for ψ(4.42)-decay. These modes are therefore forbidden (and as such they should be suppressed) according to the pseudo-dimension rule. The observed suppressions of the decays $\psi(4.03) \to D\bar{D}$ and $\psi(4.42) \to D\bar{D}$, $F\bar{F}$ are not at all surprising and, in fact, quite consistent from the point of view of the pseudo-dimension rule.

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