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LETTER TO THE EDITOR

A MODEL-INDEPENDENT PREDICTION FOR THE ISOSPIN AND G-PARITY OF THE $\Psi(4.03)$

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For the »unbound« vector charmonium $\Psi(4.03)$ the experimental determinations of the quantum numbers isospin (I) and G-parity have not yet been possible. This note predicts in a model-independent way that I^G for this resonance must be 0^- which is in conformity with the charmonium model predictions for the same.

It is well known that from the point of view of the charmonium model[1,2], the ψ-particles are interpreted as the $c\bar{c}$ states, c and $\bar{c}$ denoting the charmed quark and its antiquark, respectively. The charmed quarks being iso-scalars[1,2], the charmonium states (which include the ψ-particles) must necessarily be iso-scalars. Further, the ψ-particles are produced in e^+e^- annihilations and, therefore, they can couple to the photon. This in turn implies that these vector charmonium states must have odd C-parity like the photon. All these facts naturally lead to the conclusion that all the ψ-particles must have $I^G = 0^-$. This statement becomes immediately transparent from the following well-known relation[3]

$$G = C(-1)^I. \tag{1}$$

We have already noted that all the ψ-particles must have $I = 0$. Obviously, Eq. (1) implies that G-parity for the particles concerned must necessarily be odd since their C-parity is also odd. It may be recalled that the charmonium model predictions for I_G of the ψ-particles have been experimentally confirmed[3] for the $\psi(3.10)$

and ψ (3.69) which occur below the *OZI*-threshold (and as such they are »bound« resonances).

It may be recalled that the decays of the ψ (3.10) and ψ (3.69) are dominated by the pionic modes. Needless to mention that the decays of these »bound« resonances into particles with »open« charm are energetically *not* possible. This fact facilitates the determinations of the G-parities for the ψ (3.10) and ψ (3.69) as for these particles some decay modes consisting only of ordinary hadrons (having $S = C = 0$ where S and C denote strangeness and charm quantum numbers respectively) have been observed[3]. In this context it may be mentioned that the ψ (3.77), ψ (4.03) and ψ (4.42) occur above the charm threshold. For these »unbound« vector resonances the quark duality diagram constraint i. e. the *OZI* rule allows the decay channels which, for reasons obvious, involve particles with »open« charm. In this connection it may be mentioned that, as expected from the *OZI* rule, the ψ-particles occurring above the charm threshold have been experimentally seen to undergo hadronic decays *only* to charmed particles. This immediately implies that the G-parities of these ψ-particles cannot be determined from their observed decay modes[1-3]. This is because for non-ordinary hadrons (having non-zero scalar quantum numbers like strangeness, charm, etc.) G-parties are undefined. At this point we may note that the G-parities of the »unbound« resonances ψ (3.77) ψ (4.03) and ψ (4.42) cannot be found out by taking advantage of Eq. (1) for the difficulty of uniquely specifying the isospin of the resonances concerned from the analyses of their decay modes. This statement becomes clearer if we consider, for example, ψ (3.77)-decay. It is well known that the ψ (3.77) has been observed[3] to undergo the hadronic decay only to $D\bar{D}$. Since the charmed meson ψ (1865) is an isospinor[7], therefore, the decay ψ (3.77) $\rightarrow D\bar{D}$ suggests that the $D\bar{D}$-system can occur in either of the two isospin states, namely, $I = 1$ and $I = 0$ states. Obviously, we cannot specify in which of the two isospin states ($I = 1$ and $I = 0$) the $D\bar{D}$-system does occur without imposing additional constraint on the decay ψ (3.77) $\rightarrow D\bar{D}$. This difficulty can be, however, bypassed with the help of the selection rule for the decays of the iso-vector hadrons recently introdused by Mukhopadhyay[8]. This selection rule reads[8]: »An iso-vector meson cannot suffer a strong decay dominantly into two bosons which are iso-spinors of identical actual spins (like $K\bar{K}$ or $D\bar{D}$)«. As the ψ (3.77) suffers the dominant strong decay[3] into $D\bar{D}$, obviously then, the selection rule demands that this particle cannot be an iso-vector. This in turn implies that in the decay ψ (3.77) $\rightarrow D\bar{D}$, the $D\bar{D}$-system must have $I = 0$. This, along with the isospin invariance in strong decay ψ (3.77) $\rightarrow D\bar{D}$, clearly suggests thet the ψ (3.77) is an iso-scalar. Since for this resonance $C = -1$ (for reasons already discussed) and $I = 0$ therefore, Eq. (1) indicates that it must have odd G-parity. It is interesting to note that the selection rule[8] mentioned above enables one to predict for the ψ (3.77), with the help of Eq. (1), the value $I^G = 0^-$ which is also the charmonium model prediction for the same. This method, recently introduced by Mukhopadhyay[8] for predicting the isospin and G-parity of the ψ (3.77), can be easily extended to the vector charmonium ψ (4.03) for the same purpose. This is discussed below.

The experimental determinations for the isospin and G-parity of the ψ (4.03) is problematic as this resonance, like the ψ (3.77), has been observed to decay into iso-fermions only. In fact, for this particle two hadronic decay modes[1] $D\bar{D}^*$

and $D^*\bar{D}^*$ have been seen[1]. Further, the $D^*\bar{D}^*$ mode has been found to be the dominant[1] one for ψ (4.03)-decay. For reasons already discussed, the G-parity of the ψ (4.03) cannot be determined from the observed[1] decays ψ (4.03) $\rightarrow D\bar{D}^*$, $D^*\bar{D}^*$ (dominant). The interesting point to note regarding ψ (4.03)-decay is that its dominant strong decay mode is $D^*\bar{D}^*$ which involves two iso-spinors[7] (D^* and $\bar{D}^*$) of identical actual spins. The decaying particle ψ (4.03), therefore, cannot be an iso-vector by virtue of the selection rule[8] stated earlier. This fact rules out the value $I = 1$ out of the two possible values $I = 1$ and $I = 0$ obtained by coupling the isospins of the particles constituting the decay mode $D^*\bar{D}^*$. The isospin invariance in the strong decay ψ (4.03) $D^*\bar{D}^*$ implies that the ψ (4.03) must have $I = 0$ as the $D^*\bar{D}^*$-system can have $I = 0$ as a necessary consequence of the selction rule[8] under investigations. The value $I = 0$ for the ψ (4.03) suggests, through Eq. (1), that this particly must have odd G-parity as its C-parity is odd.

In the above we have shown that the ψ (4.03) possesses $I^G = 0^-$ which is in conformity with expectations from the charmonium model[1,2]. We conclude this note by the remark that the recent investigation predicts isospin and G-parity of the ψ (4.03) in a model-independent way.

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MODEL-NEOVISNA PREDIKCIJA IZOSPINA I G PARITETA ČESTICE Ψ (4.03)

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Dosad nije bilo moguće eksperimentalno odrediti kvantne brojeve izospina i G-pariteta »nevezanog« vektorskog čarmonija ψ (4.03). Ovo pismo predviđa na model neovisan način da je za ovu rezonancu $I^G = 0^-$ što je u skladu sa modelom čarmonija.