RADIATIVE DECAYS AND SU(3) FLAVOUR STRUCTURE OF IOTA (1460)

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Recently, Chanowitz has derived two constraints which become powerful if the experimental limits on $\Gamma(\iota \to \gamma\gamma)/B(\iota \to \bar{K}K\pi)^2$ and $\Gamma(\iota \to \varphi\gamma) \cdot B(\iota \to \bar{K}K\pi)$ are improved. It is pointed out that given the present limit on $\Gamma(\psi \to \iota\gamma)$, such a possibility appears unlikely.

In a paper with an identical title, Chanowitz [1] has argued that relationships between the radiative decay widths of the $\iota(1460)$ based on vector meson dominance (VMD) and SU(3) flavour symmetry may help decide whether the reported $\rho\gamma$ enhancement in $\psi \to \gamma\rho\gamma$ is due to iota or not. To this end, he has derived two constraints which become particularly powerful if the experimental limits [2,3] on $\Gamma(\iota\to\gamma\gamma)/B(\iota\to\bar{K}K\pi)^2$ and $\Gamma(\iota\to\varphi\gamma)\cdot B(\iota\to\bar{K}K\pi)$ are fine-tuned by factors of 2 and 6, respectively. The purpose of this letter is to show that given the present lower limit on the $\psi \to \iota\gamma$ rate, such a possibility appears highly unlikely. We first review briefly Chanowitz's work.

The iota wave function is taken as

$$\iota = \cos\theta_\iota \iota_1 + \sin\theta_\iota \iota_8 , \tag{1}$$

along with the prescription [‡1]

$$A(\iota_a \to\gamma\gamma) = \sum_V \frac{e}{f_V} A(\iota_a \to V\gamma) \quad (a = 1 \text{ or } 8, V = \rho,\omega,\varphi). \tag{2}$$

Since the vector meson-photonic couplings are related as $e/f_\rho : e/f_\omega : e/f_\varphi = 1 : 1/3 : -\sqrt{2}/3$, the following ratio is obtained:

$$A(\iota\to\gamma\gamma)/A(\iota\to\rho\gamma) = \tfrac{4}{3}(e/f_{\rho\pi\pi})G(x) , \tag{3}$$

where $G(x)$ stands for the quantity

$$G(x) = (1 + 0.5x)/(1 + x) ,$$

$$x = \tan\theta_\iota A(\iota_8 \to \rho\gamma)/A(\iota_1 \to\rho\gamma) , \tag{4}$$

and possible off-shell corrections in going from $q^2 = m_V^2$ to $q^2 = 0$ have been partially accounted [‡2] for by writing $f_{\rho\pi\pi}$ in place of f_ρ. Note that $f_{\rho\pi\pi}$ is given by $f^2_{\rho\pi\pi}/4\pi = 3m_\rho^2\Gamma_\rho/2|\bar{k}_{\rho\pi\pi}|^3 = 2.97 \pm 0.10$.

To calculate the rate for $\iota \to \pi\pi\gamma$, it has been assumed that this process is induced by $\rho\gamma$ and an evaluation of the three-body phase space yields

$$\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma) = (0.80)\,[(m_\iota^2 - m_\rho^2)^3/32\pi m_\iota^3]\,|A(\iota\to\rho\gamma)|^2 . \tag{5}$$

Combining (3) and (5) and using the SU(3) relations among $A(\iota_a \to V\gamma)$ the following results are obtained [‡1]

$$\Gamma(\iota\to\gamma\gamma)/\Gamma(\iota\to\rho\gamma\to\pi\pi\gamma) = 0.625(1 - m_\rho^2/m_\iota^2)^{-3}(1.34\, e/f_{\rho\pi\pi})^2 G^2(x), \tag{6a}$$

$$\Gamma(\iota\to\omega\gamma) = 0.085\,\Gamma(\iota\to\rho\gamma\to\pi\pi\gamma) , \tag{6b}$$

$$\Gamma(\iota\to\varphi\gamma) = 0.063\,H^2(x)\,\Gamma(\iota\to\rho\gamma\to\pi\pi\gamma) , \tag{6c}$$

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‡1 The followed convention is followed:

$$\Gamma(V\to e^+e^-) = \tfrac{1}{3}\alpha^2 m_V (f_V^2/4\pi)^{-1} ,$$

$$\Gamma(\iota\to V\gamma) = [(m_\iota^2 - m_V^2)^3/32\bar{\kappa} m_\iota^3]\,|A(\iota\to V\gamma)|^2 ,$$

$$\Gamma(V\to\iota\gamma) = [(m_V^2 - m_\iota^2)^3/96\pi m_V^3]\,|A(V\to\iota\gamma)|^2 .$$

Experimentally, $f_\rho^2/4\pi = 1.93 \pm 0.10$, $f_\omega^2/4\pi = 21.0 \pm 1.4$, $f_\varphi^2/4\pi = 13.8 \pm 0.6$ and $f_\psi^2/4\pi = 11.8 \pm 1.6$.

‡2 See ref. [1] for a discussion on this point.

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where $H(x)$ is another function of x given by

$$H(x) = (1-2x)/(1+x)\,. \tag{7}$$

It may be noted that the current experimental limits [2] on $\Gamma(\iota \to \gamma\gamma)\cdot B(\mathrm{i} \to \bar{K}K\pi)$, $\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)/B(\iota \to \bar{K}K\pi)$ and $\Gamma(\iota \to \varphi\gamma)/\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)$ give ‡3 the following bounds for $G(x)$ and $H(x)$

$$|G(x)| < 0.74 \pm 0.14\,, \quad |H(x)| < 5.1 \pm 0.6\,, \tag{8a,b}$$

leading to

$$x \geqslant 1.1 \text{ or } x \leqslant -2.0\,, \tag{8c}$$

Chanowitz now makes the following interesting observation: If the experimental limits on the above ratios are improved so that $|G(x)|$ and $|H(x)|$ are less than their asymptotic values (viz. 0.5 and 2, respectively) then $|G(x)| < 1/2$ would imply $x < -1.5$ and $|H(x)| < 2$ would imply $x > -0.25$ which are mutually incompatible conditions. One would then be led to conclude that the $\rho\gamma$ enhancement cannot be realised due to the iota only.

Although the analysis so far appears to be perfect, one gets into difficulty if one tries to seek consistency with the $\psi \to \iota\gamma$ rate. For, one can extend (2) to include the $\psi(3097)$ state and then assuming $\psi(3097)$ to be a $c\bar{c}$ state, one can obtain

$$A(\iota_8 \to \rho\gamma) : A(\iota_8 \to \omega\gamma) : A(\iota_8 \to \varphi\gamma) : A(\iota_8 \to \psi\gamma) = 1 : \tfrac{1}{3} : \tfrac{2}{3}\sqrt{2} : 0\,, \tag{9a}$$

$$A(\iota_3 \to \rho\gamma) : A(\iota_1 \to \omega\gamma) : A(\iota_1 \to \varphi\gamma) : A(\iota_1 \to \psi\gamma) = 1 : \tfrac{1}{3} : -\tfrac{1}{3}\sqrt{2} : \tfrac{2}{3}\sqrt{2}\,, \tag{9b}$$

$$e/f_\rho : e/f_\omega : e/f_\varphi : e/f_\psi = 1 : \tfrac{1}{3} : -\tfrac{1}{3}\sqrt{2} : \tfrac{2}{3}\sqrt{2}\,. \tag{9c}$$

The ratio of $A(\psi \to \iota\gamma)$ and $A(\iota \to \rho\gamma)$ would then be given by

$$A(\psi \to \iota\gamma)/A(\iota \to \rho\gamma) = \tfrac{2}{3}\sqrt{2}f(x)\,, \tag{10}$$

where $f(x)$ stands for

$$f(x) = 1/(1+x)\,. \tag{11}$$

‡3 The current experimental status is

$\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)/B(\iota \to \bar{K}K\pi) = 2.0 \pm 0.75$ MeV ,

$\Gamma(\iota \to \gamma\gamma)\cdot B(\iota \to \bar{K}K\pi) < 2$ keV ,

$\Gamma(\iota \to \varphi\gamma)/\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma) < 1.6 \pm 0.4$,

$B(\iota \to \bar{K}K\pi) > \frac{1}{2}$.

Thus one would find

$$\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma) = \tfrac{27}{10}\,[m_\psi(m_\iota^2 - m_\rho^2)/m_\iota(m_\psi^2 - m_\iota^2)]^3 f^2(x)\,\Gamma(\psi \to \iota\gamma)\,, \tag{12a}$$

or

$$\Gamma(\psi \to \iota\gamma) = 4.4 f^2(x)\,\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)\,. \tag{12b}$$

In other words

$$\Gamma(\psi \to \iota\gamma) > 4.41 f^2(x)\,\text{MeV} \tag{13a}$$

if one uses the present experimental upper limit on $\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)$. On the other hand, recent results (see ref. [3]) on radiative decays of ψ obtained by the Mark III and the Crystal Ball groups suggest the following lower limit on the branching fraction of $\psi \to \gamma\iota(1460)$:

$$B(\psi \to \gamma\iota(1460)) > (6.9 \pm 0.4 \pm 1.0) \times 10^{-3}\,. \tag{13b}$$

In order that (13a) and (13b) are mutually consistent, $|x|$ must be of $O(10^2)$ so that $G(x)$ and $H(x)$ are very close to their asymptotic values. Note that this value of $|x|$ is *not* inconsistent with the present limits on $|G(x)|$ and $|H(x)|$ (see eq. (8)). Since $|x|$ is very large, the coefficients in the numerator and denominator prevail. Therefore, if consistency with the $\Gamma(\psi \to \iota\gamma)$ is to be maintained, it is highly unlikely that $G(x)$ or $H(x)$ would have values appreciably smaller than 1/2 or −2, respectively. For instance, if $G(x) = -0.4$ then $x = -1.7$ ($\gg -100$). This means that for a 20% deviation from $|G(x)| = 0.5$, x has to shrink by at least a couple of orders of magnitude.

One can conceive of a possibility [4] that ι has a significant gluon component

$$\iota = a\iota_8 + b\iota_1 + c\iota_9\,, \quad a^2 + b^2 + c^2 = 1\,. \tag{14}$$

However, this does not improve the situation much. For, using (14), one can obtain the following relations

$$A(\psi \to \iota\gamma)/A(\iota \to \rho\gamma) = [\tfrac{2}{3}\sqrt{2} + M(\psi,\iota_9)]/(1+x)\,, \tag{15a}$$

$$A(\iota \to \gamma\gamma)/A(\iota \to \rho\gamma) = \tfrac{4}{3}(e/f_\rho) \times [1 + 0.5x + \tfrac{2}{3}\lambda\psi + (1/\sqrt{2})\lambda\psi M(\psi,\iota_9)]/(1+x)\,, \tag{15b}$$

where x and $M(\psi, \iota_9)$ are defined as

$$x = (a/b)A(\iota_8 \to \rho\gamma)/A(\iota_1 \to \rho\gamma)\,, \tag{16a}$$

$$M(\psi, \iota_9) = (c/b)A(\psi \to \iota_9\gamma)/A(\iota_1 \to \rho\gamma)\,, \tag{16b}$$

and λ_ψ is a suppression factor to account for the extrapolation from $q^2 = m_\psi^2$ to $q^2 = 0$. Eliminating $M(\psi, \iota_9)$, the following relation emerges

$$A(\iota \to \gamma\gamma)/A(\iota \to \rho\gamma) - \tfrac{2}{3}\sqrt{2}(e/f_\rho)\lambda_\psi A(\psi \to \iota\gamma)/A(\iota \to \rho\gamma) = \tfrac{4}{3}(e/f_\rho)G(x). \quad (17)$$

This enables one to express $\Gamma(\iota \to \gamma\gamma)/\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma)$ in a similar form as (6a)

$$\Gamma(\iota \to \gamma\gamma)/\Gamma(\iota \to \rho\gamma \to \pi\pi\gamma) = 0.625(1 - m_\rho^2/m_\iota^2)^{-3}(1.34e/f_{\rho\pi\pi})^2 g^2(x)\,, \quad (18a)$$

where $g(x)$ is related to $G(x)$ as

$$g^2(x) = G^2(x)/|1 \pm 0.027\lambda_\psi\,[\Gamma(\psi \to \iota\gamma)/\Gamma(\iota \to \gamma\gamma)]^{1/2}|^2\,. \quad (18b)$$

However, the bound on $|G(x)|$ in (8a) should now be applied to $|g(x)|$. Thus

$$|G(x)| < (0.74 \pm 0.14) \times |1 \pm 0.027\lambda_\psi[\Gamma(\psi \to \iota\gamma)/\Gamma(\iota \to \gamma\gamma)]^{1/2}|\,. \quad (19)$$

If the RHS is <0.5, then $|G(x)|$ is *certainly* less than 0.5 and Chanowitz's analysis goes through. However, this would mean either

$$[\Gamma(\psi \to \iota\gamma)/\Gamma(\iota \to \gamma\gamma)]^{1/2} > 0.3/0.027\lambda_\psi \approx 10\lambda_\psi^{-1}\,, \quad (20a)$$

or

$$[\Gamma(\psi \to \iota\gamma)/\Gamma(\iota \to \gamma\gamma)]^{1/2} < 1.67/0.027\lambda_\psi \approx 60\lambda_\psi^{-1}\,. \quad (20b)$$

Even if $\lambda_\psi \approx O(1)$, we should either have $\Gamma(\psi \to \iota\gamma) \gg \Gamma(\iota \to \gamma\gamma)$ or $\Gamma(\psi \to \iota\gamma) \ll \Gamma(\iota \to \gamma\gamma)$. Neither the theoretical nor the experimental limits on $\Gamma(\iota \to \gamma\gamma)$ seem to favour such a possibility.

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References

[1] M.S. Chanowitz, Phys. Lett. B 164 (1985) 379.
[2] J. Richman, Ph.D. thesis, report CALT-68-1231 (1985).
[3] N. Wermes, Invited talk Physics in Collision V Conf. (Autun, France, July 1985), preprint SLAC-PUB-3730.
[4] J.L. Rosner, Phys. Rev. D27 (1983) 1101;
B. Baghi anr A. Lahiri, J. Phys. G 12 (1986) 479.