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SU(3) PROPERTIES OF THE NEW PARTICLESA PROBLEM FOR UNIFIED GAUGE THEORIES ?

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A B S T R A C T

We show that if the ψ or the ψ' should have an SU(3) non-singlet piece this is incompatible with the "conventional" unified gauge theory picture of a strong gauge group coupled to colour which commutes with the weak and electromagnetic gauge group.

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In this note we examine the constraints on building gauge theory models of the weak and electromagnetic interactions which would arise if the ψ and/or ψ' have an $SU(3)$ non-singlet piece.

Some information concerning the $SU(3)$ properties of the ψ and ψ' may be obtained from recent results ¹⁾ on the decays of the ψ and ψ' .

1) The decays $\psi \rightarrow M_1 + M_2$ where M_1 and M_2 are mesons belonging to octets of the same C , the $SU(3)$ generalization of charge conjugation, are below 10% of the decays where M_1 and M_2 have opposite C . This suggests that the ψ is an $SU(3)$ singlet and that the former decays [SU(3) forbidden] occur through $SU(3)$ breaking.

2) $\psi' \rightarrow \psi \eta$ has been observed with a branching ratio $4 \pm 2\%$. If both ψ and ψ' were $SU(3)$ singlets and the η were pure octet this decay would be $SU(3)$ forbidden and should occur only through $SU(3)$ breaking effects. However, the branching ratio seems rather large when compared with the $SU(3)$ allowed decay $\psi' \rightarrow \psi \pi \pi$ which has a branching ratio approximately 50%, since the phase space of the p wave decay $\psi' \rightarrow \psi \eta$ is smaller than the s wave decay $\psi' \rightarrow \psi \pi \pi$.

The admixture of a small amount of $SU(3)$ singlet to the η ($\eta \simeq \cos 10^\circ \eta_8 + \sin 10^\circ \eta_1$) would not significantly affect this conclusion. Of course, this is by no means conclusive proof that ψ' has a non-singlet piece ; $SU(3)$ breaking effects could be much larger.

However, we wish to point out that if we assume the ψ or ψ' decays do turn out to be too big to be accounted for by $SU(3)$ breaking effects alone and require $SU(3)$ non-singlet pieces for the ψ and/or ψ' , this rules out a large (and theoretically favoured) class of gauge theories. These include not just the conventional charmed models where the ψ and ψ' are necessarily $SU(3)$ scalars but models such as those of Ref. 2) which have ψ and/or ψ' $SU(3)$ non-singlets provided the strong gauge group commutes with the weak and electromagnetic gauge group and there are no strongly interacting scalars.

The construction of a gauge theory for the strong, weak and electromagnetic interactions must be done in such a way as to accommodate the strong interaction symmetries (parity, strangeness, baryon number, isotopic spin). Moreover, it is aesthetically desirable that this be done

in such a way that these symmetries are natural in the sense that they are not achieved by setting a counter term just to make the corrections to these symmetries of order G_F . To satisfy these requirements we are led to consider models ³⁾ in which (i) the weak gauge group G_W commutes with the strong (colour) gauge group G_S (ii) there are no strongly interacting scalars.

With such a model it is straightforward to show ³⁾ that the Lagrangian may be expanded in the form

$$\mathcal{L} = - \bar{\Psi}_{\alpha i} \gamma^\mu D_\mu^S \Psi_{i\alpha} - \bar{\Psi}_{\alpha i} m_{ij} \Psi_{j\alpha} - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} + O(e) \quad (1)$$

where there is a sum assumed over the internal indices i, j and the colour indices α . D_μ^S is the G_S covariant derivative.

Thus the strong interaction symmetries are the symmetries of the mass matrix.

If we have two sets of quarks, light q_L and heavy q_H , then we have

$$\mathcal{L} = - \bar{q}_L \not{D} q_L - \bar{q}_L m_L q_L - \bar{q}_H \not{D} q_H - \bar{q}_H m_H q_H - \frac{1}{4} F_{\mu\nu} F^{\mu\nu} + O(e) \quad (2)$$

where indices have been suppressed.

The ψ and ψ' will be constructed from heavy quarks q_H and the conventional particles will be constructed from the light quarks q_L . No large mixing of light and heavy quarks can be accommodated since we must appeal to the Okubo-Iizuka-Zweig rule to suppress the decays of ψ and ψ' .

If there is an approximate $SU(3)$ symmetry of the strong interactions under which both conventional hadrons and/or the ψ or ψ' transform non-trivially then the Lagrangian must also have this approximate symmetry. This may only be achieved if both the mass matrices m_L and m_H are approximately $SU(3)$ symmetric. However, this means the Lagrangian is approximately

invariant under a larger symmetry than this $SU(3)$; namely $SU(3)_L$ acting only on q_L and $SU(3)_H$ acting only on q_H . These will separately be as good symmetries as the diagonal subgroups under which both q_L and q_H transform.

Since L is made up, to order e , only of the mass matrix no term is possible which would break this symmetry to the diagonal subgroup (if, for example, strongly interacting scalars had been allowed this would not have been true).

But now decays, such as $\psi' \rightarrow \psi \eta_8$, which, by our assumption were too big to be explained purely by $SU(3)$ breaking effects, are forbidden by $SU(3)_L$ or $SU(3)_R$ separately although allowed by the diagonal $SU(3)$ subgroup ^{*}). This contradicts our initial assumption.

Thus confirmation of an $SU(3)$ non-singlet piece in ψ or ψ' beyond $SU(3)$ breaking effects, would mean the "conventional" gauge theory picture of the strong, weak and electromagnetic interactions is untenable.

It is of great interest to determine if this is true. However, this may be difficult in practice. $SU(3)$ breaking effects may be larger than expected. Comparison of $SU(3)$ allowed ψ decay rates suggests possible large violations of $SU(3)$ ¹⁾. Since these decays have already been suppressed by the Okubo-Iizuka-Zweig rule it may be $SU(3)$ breaking effects are relatively enhanced. Clearly we must understand these effects before reaching definite conclusions regarding the symmetry properties of the ψ and ψ' . If a decay such as $\psi' \rightarrow K_L K_S$ were observed significantly larger than that for $\psi \rightarrow K_L K_S$ this would strongly support the hypothesis that the ψ' has an $SU(3)$ non-singlet piece since it is difficult to see why $SU(3)$ breaking effects should be significantly different between these processes. It has also been suggested that radiative decays may give useful information on the symmetry properties of the ψ and the ψ' ⁴⁾

^{*}) Harari ²⁾ has two schemes, the U scheme in which $SU(3)_L$ and $SU(3)_H$ are exact and the O scheme in which only the diagonal $SU(3)$ is exact [with an over-all $O(6)$ symmetry]. He finds the O scheme is incompatible with a gauge theory but for a different reason than ours - some of the generators he needs to describe the weak currents lie outside the $O(6)$. However, using other charge assignments this difficulty can be circumvented [see the last two papers of Ref. 2] but not, we believe, the difficulties discussed here.

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