# Remarks on the change of the weak current and elimination of anomalies in gauge models of weak and electromagnetic interactions

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Modifications containing no anomalies are proposed for the model of De Rujula, Georgi, and Glashow [Phys. Rev. Lett. **35**, 69, (1975)].

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The discovery of new particles is in many respects a brilliant confirmation of the predictions of the scheme with four quarks, in which weak and electromagnetic interactions are described by a gauge theory with spontaneously broken $SU(2) \otimes U(1)$ symmetry.[1] The particles are combined here into weak multiplets in the following fashion:

$$\begin{pmatrix} \nu \\ e \end{pmatrix}_L, \quad e_R, \quad \begin{pmatrix} \nu' \\ \mu \end{pmatrix}_L, \quad \mu_R,$$

$$\begin{pmatrix} p \\ n^\theta \end{pmatrix}_L, \quad \begin{pmatrix} p' \\ \lambda^\theta \end{pmatrix}_L, \quad p_R, \quad n_R^\theta, \quad p'_R, \quad \lambda_R^\theta,$$

$$n^\theta = n\cos\theta + \lambda\sin\theta; \quad \lambda^\theta = -n\sin\theta + \lambda\cos\theta.$$

The gauge theory of weak and electromagnetic interactions in this model, with allowance for three quark colors, does not contain $\gamma_5$ anomalies, and the charged weak current has a $(V-A)$ structure:

$$J_\mu = \bar{p}_L\gamma_\mu n_L^\theta + \bar{p}'_L\gamma_\mu\lambda_L^\theta + \bar{\nu}_L\gamma_\mu e_L + \bar{\nu}'_L\gamma_\mu\mu_L.$$

To explain the constant $K$-meson yield in the process $e^+e^- \to$ hadrons in the energy region 3–8 GeV, and also to explain the rule $\Delta I = \frac{1}{2}$ and the anomalous velocity of nonleptonic decays of strange particles, it was proposed in[2] to modify the charmed charged current, adding a term with $(V+A)$ structure

$$J'_\mu = J_\mu + \bar{p}'_R\gamma_\mu n_R,$$

which corresponds to the following change in the combination of particles into isomultiplets:

$$\begin{pmatrix} p \\ n^\theta \end{pmatrix}_L, \quad \begin{pmatrix} p' \\ \lambda^\theta \end{pmatrix}_L, \quad \begin{pmatrix} p' \\ n \end{pmatrix}_R, \quad \lambda_R, \quad p_R.$$

This modification of the hadron sector with lepton sector unchanged leads to the appearance of anomalies in the gauge model of the weak and electromagnetic interactions of leptons and hadrons.

In this article we wish to call attention to the most economical method of modifying the model of[2] so as to compensate for the anomalies. This can be done either by introducing new quarks[3] or by modifying the lepton sector.[2] We discuss first the last possibility. We introduce two new leptons, massive charged $U$ and massless neutral $\nu''$ with the following breakdown into isotopic multiplets:

$$\begin{pmatrix}\nu'' \\ U\end{pmatrix}_R, \quad U_L,$$

which leads to a change of the charged weak current

$$J''_\mu = J'_\mu + \bar{\nu}''_R \gamma_\mu U_R .$$

It is easily seen that this modification of the lepton sector, with allowance for the quark colors, frees the gauge model of anomalies.[1)] We note that in recent experiments at Stanford they observed events $e^+e^- \to \mu^\pm + e^\mp + \ldots$, which were attributed, in particular,[5] to possible production of a pair of new massive charged leptons $U^\pm$ and their subsequent decay $U^\pm \to \mu^\pm(e^\pm)\bar{\nu}\nu$. Such an interpretation of the $\mu e$ events makes it easy to explain the large value of $R = \sigma(e^+e^- \to \text{hadrons})/\sigma(e^+e^- \to \mu^+\mu^-) = 5.5 \pm 0.5$ at energies from 4 to 8 GeV,[6] although it does not solve the problems completely. Taking the statements made above concerning the renormalizable theory of weak and electromagnetic interactions of leptons and hadrons, such an interpretation of the $\mu e$ events seems quite likely.

If we wish to eliminate the anomalies of the model of[2] only by changing the hadron sector, then we must introduce at least two new quarks $g$ and $t$, with charges $Q_g = -\frac{1}{3}$ and $Q_t = \frac{2}{3}$; the additional multiplets are chosen in the form

$$\begin{pmatrix} t \\ g\end{pmatrix}_L, \quad g_R, \quad t_R .$$

It is suggested in[7] that $\psi(3095)$ and $\psi'(3684)$ are possibly bound $g\bar{g}$ quark-antiquark states. In such a model there are no anomalies of three quark colors are taken into account, and the weak charged current takes the form

$$J''_\mu = J'_\mu + \bar{t}_L \gamma_\mu g_L .$$

There is also a third possibility of modifying the model of[2], in which the anomalies are compensated for separately in both the lepton and hadron sectors. An example is a model containing a fifth quark $g$ and four new leptons, two of which are massive and charged and two are neutral and masses; these leptons are joined into the multiplets[2)]

$$\begin{pmatrix} p \\ g\end{pmatrix}_R, \quad g_L, \quad \begin{pmatrix}\nu'' \\ U\end{pmatrix}_R, \quad U_L, \quad \begin{pmatrix}\nu''' \\ V\end{pmatrix}_R, \quad V_L ,$$

where $V$ is the fourth charged lepton. The charged current is then

$$J''_\mu = J'_\mu + \bar{p}_R\gamma_\mu g_R + \bar{\nu}''_R \gamma_\mu U_R + \bar{\nu}'''_R \gamma_\mu V_R .$$

The question of modification of the neutral current in all the models considered above will be discussed separately.

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1)Two additional massive leptons were introduced similarly in a model of weak and electromagnetic interactions with *CP*-violation in[4].

2)The hadron sector of this model coincides with the model of Nikolaev.[8]

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