FIVE QUARK MODELS AND MAGNETIC MOMENTS OF BARYONS. I

By A. L. Choudhury

Departments of Physics and Mathematics, Elizabeth City State University*

(Received April 5, 1978)

Introducing a fifth quark f with electric charge $Q = 2/3$, and assuming that the particle classification follows the C–C' model mentioned by Achiman, Kollar and Walsh, we have derived the magnetic moments of all baryons under U(5)-symmetry. The normal and charmed particles have the same magnetic moments expressed in terms of at most three arbitrary constants, as those obtained in U(4)-symmetry. We predict the moments of new baryons, which turn out to be inevitable if Y-spectroscopy indicates the existence of a new quark. We have also evaluated magnetic moments of baryons for an alternative model with f-quark charge $Q = -1/3$ to accomodate the possible bias of the experimental results.

1. Introduction

Recently with the discovery of Y and Y'[1], the existence of another quark is very much in the air. These resonances are being speculated as bound states of a new quark-antiquark states [2]. The situation is very much similar to the case, when J/ψ and other closely lying resonance states were discovered by the end of 1974 [3].

The necessity of more quarks has been speculated by many authors [4]. The standard GIM model [5] with four quarks and four leptons predict the value of R defined as

$$R = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)}$$

to have a value 10/3 [5]. This value is much less than the value that we find experimentally. The value of R settles down around a value of 5 for the high energy region. Theoretically to explain this higher value of R, it is generally conjectured that more quarks would be inevitable. The most popular trend is naturally to introduce quarks in pairs to retain weak interaction gauge symmetry of the type $SU(2)\otimes U(1)$ according to the prescription of the Weinberg-Salam model or models closely similar to it [7]. To eliminate from such theories

* Address: Departments of Physics and Mathematics, Elizabeth City State University, Elizabeth City, N. C. 27909, USA.

the triangular anomaly, we need to introduce for each pair of quarks, a pair of leptons. Harari [8] proposed the introduction of two more quarks $\begin{pmatrix} t \\ b \end{pmatrix}$ in the set of the already existing GIM model the quark pairs $\begin{pmatrix} u \\ d' \end{pmatrix}$ and $\begin{pmatrix} c \\ s' \end{pmatrix}$. This would give R value 5. But we also need two more leptons $\begin{pmatrix} \nu_L \\ L^- \end{pmatrix}$ in addition to existing pairs $\begin{pmatrix} \nu_e \\ e^- \end{pmatrix}$ and $\begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix}$ to eliminate the triangular anomaly mentioned earlier. There are other models which are closely related to the Harari model [9].

Although such models are very attractive for their symmetrical foundation, they are still highly speculative and open to critical scrutiny. However, it does not bar us altogether to try out other models which are of somewhat different symmetry origin. An interesting model proposed by Achiman, Kollar and Walsh [10] needed only five quarks. In addition to the standard GIM four quarks, they introduced a new quark f with $Q = 2/3$, $Y = -2/3$, $C = 0$, and a new quantum number $C' = 1$. This model gives the R-value 14/3, which is not very far off from the experimental value. When we want to incorporate this model into the weak interaction theory in order to remove the triangular anomaly, we need two heavy leptons, in addition to e^- and μ^-. This version has been called by them as the $C-C'$ version of SU(5)-symmetry.

Recently Choudhury [11] used this model to calculate in SU(10)-symmetry the magnetic moments of vector mesons. In that calculation the author assumed that ψ' (3.7) to be the quark-antiquark combination of a new quark f. However we are aware that ψ' can be interpreted as the radial excitation of $c\bar{c}$. Since the observation of Y-family of new resonances by Herb et al. [1], many authors like Lichtenberg et al. and Carlson et al. [2] are interpreting Y (9.5) as the bound state of a new quark-antiquark combination. If we assume Y (9.5) to be the $f\bar{f}$ bound ground state, then we have a distinct prediction under SU(10)-symmetry that the magnetic moment of the new particle must satisfy the following relation

$$\mu(Y) = (64/25)\mu(\varrho^0) \quad \text{for } Q(\mathrm{f}) = 2/3,$$

$$\mu(Y) = -(28/25)\mu(\varrho^0) \quad \text{for } Q(\mathrm{f}) = -1/3.$$

As soon as we are convinced that the new quark is inevitable, i.e., that the most reasonable interpretation of T is the new quark-antiquark combination, we are forced to introduce new baryon states, which we expect to observe sooner or later. In the following, we would assume that Y is a positive indication of a new quark which we would call the fancy quark. Although Carson et al. [2] have indicated that the possibility of the absolute value of the charge of the new quark is $|Q| = 1/3$, the value of the charge magnitude $Q = 2/3$ has not been completely ruled out. In the first phase we would assume that the Q-value of the f-quark is 2/3 as postulated by Achiman, Kollar and Walsh [10] and later by Choudhury [11]. Then in the second phase we would slightly modify the C—C' model by assuming that the f-quark has a charge $Q = -1/3$. In the first phase ($Q = 2/3$) we would assume that the intrinsic quantum numbers satisfy the extended Gell-Mann–

–Nishijima formula

$$Q = I_3+(Y/2)+C_1+C_2.$$

On the other hand for the second phase ($Q = -1/3$) we assume a different Gell-Mann–
–Nishijima formula

$$Q = I_3+(Y/2)+C_1-C_2.$$

In this paper we would assume U(5) symmetry and follow the technique described in U(4)-symmetry calculations [12] to compute the magnetic moments of the new baryons which would show up with the introduction of the new quark f. All results derived under U(4)-symmetry will be shown to be also valid for those baryons, which are expected to appear under that symmetry.

In a future paper we would extend the results in U(10)-symmetry which will be a natural extention to incorporate the spin of the particles.

We are aware of the fact that the symmetry breaking interaction upsets many of the results as has been shown recently by Lichtenberg and others [13] but we think that for future experimental comparison it is quite reasonable to know the theoretical predictions of different symmetries. The magnitude of the deviation of the results might also offer deeper insight into the symmetry breaking interactions, which are far from being explained fully.

In Section 2 we introduce the basic rules of the quark model and described how to obtain the baryon tensors. We have also defined there the particle nomenclatures in C—C' model of U(5). In Section 3 we describe the construction of the most general current tensors and derived the magnetic moments of baryons in terms of three or fewer constants. In Section 4 we introduce the modified model with $Q = -1/3$ for the f-quark and obtained the magnetic moments for the baryons. In Section 5 we discuss our results.

2. *Particle classification and multiplet tensors*

Following the C—C' version of Achiman, Kollar and Walsh [10] types of U(5)-symmetry, we introduce a fancy quark f in addition to the four quarks, a pair of up and down quarks u and d, a strange quark s and a charmed quark c. This new quark we require to possess a charge $Q = 2/3$, $Y = -2/3$ and charm quantum number $C = 0$. But this f-quark should carry a new quantum number fancy designated by C' with $C' = 1$. For all other quarks $C' = 0$. The quantum numbers of these basic quarks must satisfy the modified Gell-Mann–Nishijima formula

$$Q = I_3+(Y/2)+C+C'. \tag{1}$$

As usual, we assume that the baryons are constructed out of a qqq-combination of the basic quarks. This combination yields the representations (see Table I)

$$\underline{\underline{5}}\otimes\underline{\underline{5}}\otimes\underline{\underline{5}} = \underline{\underline{35}}+2\times\underline{\underline{40}}+\underline{\underline{10}}. \tag{2}$$

TABLE I

Dimensional equations of the baryon classification under five quark model

$\underline{\underline{5}}\otimes\underline{\underline{5}}\otimes\underline{\underline{5}} = \underline{\underline{35}}+2\times\underline{\underline{40}}+\underline{\underline{10}}$
$U(5) \rightarrow U(4)\otimes U_2$
$\underline{\underline{40}} = (\underline{20}', 0)+(\underline{10}'+\underline{6}', 1)+(\underline{4}', 2)$
$\underline{\underline{35}} = (\underline{20}, 0)+(\underline{10},1)+(\underline{4}, 2)+(\underline{1}, 3)$
$\underline{\underline{10}} = (\underline{\bar{4}}, 0)+(\underline{6}'', 1)$
$U(4) \rightarrow SU(3)\otimes U_1$
$\underline{20}' = (8, 0)+(6+\bar{3}, 1)+(3,2)$
$\underline{10}' = (6, 0)+(3, 1)+(1, 2)$
$\underline{6}' = (\bar{3}, 0)+(3, 1)$
$\underline{4}' = (3, 0)+(1,1)$
$\underline{20} = (10, 0)+(6, 1)+(3, 2)$
$\underline{10}$ and $\underline{4}$ split similar to $\underline{10}'$ and $\underline{4}'$ respectively
$\underline{1} = (1, 0)$
$\underline{\bar{4}} = (1, 0)+(\bar{3}, 1)$
$\underline{6}''$ splits similar to $\underline{6}'$

The representation $\underline{\underline{35}}$ is totally symmetric with respect to the quark contents and the decouplet baryons are to be placed there. The mixed representation $\underline{\underline{40}}$ should contain the baryon octet. In terms of $U(4)\otimes U_2$ content we can write for $\underline{\underline{40}}$-representation

$$\underline{\underline{40}} = (\underline{20}',0)+(\underline{10}'+\underline{6}',1)+(\underline{4}',2), \tag{3}$$

where $(\underline{m}, n)$ stands for the representation $\underline{m}$ belonging to U(4) and n the eigenvalue of the additive fancy quantum number C'. In the above representations a double underlined number belongs to U(5) multiplet. The representations belonging to SU(3) will not be underlined.

The representations $\underline{20}'$, $\underline{10}'$, $\underline{6}'$, and $\underline{4}'$ (belonging to U(4)) can further be split up in terms of $SU(3)\otimes U_1$ contents as follows:

$$\underline{20}' = (8,0)+(6,1)+(\bar{3},1)+(3,2), \tag{4a}$$

$$\underline{10}' = (6,0)+(3,1)+(1,2), \tag{4b}$$

$$\underline{6}' = (\bar{3},0)+(3,1), \tag{4c}$$

$$\underline{4}' = (3,0)+(1,1). \tag{4d}$$

The symbol (m, n) in Eqs (4a)—(4d) indicates the dimension m (without underline) of the SU(3) content of the representation and the charm quantum number n. If we want the tensor $\mathfrak{B}_{\{ac\}b}$ to represent $\underline{\underline{40}}$-multiplet with a, b, c to run from 1 through 5, we can write as in CJ1 [12]

$$\mathfrak{B}_{\{ac\}b} = \delta^{\kappa}_{a}\delta^{\sigma}_{b}\delta^{\theta}_{c}B^{20'}_{\{\kappa\theta\}\sigma} + \frac{1}{\sqrt{2}}(\delta^{\kappa}_{a}\delta^{\sigma}_{b}\delta^{5}_{c} - \delta^{\kappa}_{c}\delta^{\sigma}_{b}\delta^{5}_{a})B^{10'}_{\kappa\sigma}$$
$$+ \frac{1}{\sqrt{6}}(2\delta^{\kappa}_{a}\delta^{5}_{b}\delta^{\sigma}_{c} + \delta^{5}_{a}\delta^{\kappa}_{b}\delta^{\sigma}_{c} - \delta^{\sigma}_{a}\delta^{\kappa}_{b}\delta^{5}_{c})B^{6'}_{\{\kappa\sigma\}}$$
$$+ \frac{1}{\sqrt{2}}(\delta^{\kappa}_{a}\delta^{5}_{b}\delta^{5}_{c} - \delta^{\kappa}_{c}\delta^{5}_{a}\delta^{5}_{b})B^{4'}_{\kappa}. \tag{5}$$

The above tensor is antisymmetric with respect to two indices within the curly bracket. The Greek indices run from 1 through 4. One of the tensors of the right hand side of the Eq. (5) has already been given in CJ1 (Eq. (7)). It is normalized to the particle number in the multiplet. For the sake of completeness, we give the expression again:

$$B^{20'}_{\{\mu\varrho\}\nu} = \delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{k}_{\varrho}N^{00}_{\{ik\}j} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{4}_{\varrho} - \delta^{i}_{\varrho}\delta^{j}_{\nu}\delta^{4}_{\mu})S^{10}_{ij}$$
$$+ \frac{1}{\sqrt{6}}(2\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{j}_{\varrho} + \delta^{4}_{\mu}\delta^{i}_{\nu}\delta^{j}_{\varrho} - \delta^{j}_{\mu}\delta^{i}_{\nu}\delta^{4}_{\varrho})T^{10}_{\{ij\}}$$
$$+ \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{4}_{\varrho} - \delta^{i}_{\varrho}\delta^{4}_{\nu}\delta^{4}_{\mu})T^{20}_{i}. \tag{5a}$$

Similarly for $\underline{10}'$, $\underline{6}'$, and $\underline{4}'$ representations we can derive the following expressions

$$B^{10'}_{\mu\nu} \doteq \delta^{i}_{\mu}\delta^{j}_{\nu}S^{01}_{ij} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu} + \delta^{i}_{\nu}\delta^{4}_{\mu})T^{11}_{i} + \delta^{4}_{\mu}\delta^{4}_{\nu}L^{21}, \tag{5b}$$

$$B^{6'}_{\{\mu\nu\}} = \delta^{i}_{\mu}\delta^{j}_{\nu}T^{01}_{\{ij\}} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu} - \delta^{i}_{\nu}\delta^{4}_{\mu})T^{11}_{i}, \tag{5c}$$

$$B^{4'}_{\mu} = \delta^{i}_{\mu}T^{02}_{i} + \delta^{4}_{\mu}L^{12}. \tag{5d}$$

In the above expressions i, j, and k are the SU(3) indices which run from 1 through 3. The tensor $B^{10'}_{\mu\nu}$ is totally symmetric whereas $B^{6'}_{\{\mu\nu\{}$ is totally antisymmetric with respect to the indices μ and ν. We introduce the following notation to designate the particles belonging to SU(3)-multiplets: a term $A^{mn}_{\dots}$ indicates to which multiplet the particles belong (for example if $A = N$, it belongs to the octet, if $A = S$ it belongs to the sextet and so on), and the suffixes m and n stand for the eigenvalues of C and C' respectively. We would follow Gaillard, Lee, and Rosner [14] for the identification of the particles. Thus for the sextet S^{10}_{ij} we would write

$$S^{10}_{11} = C^{++}_{10}, \quad S^{10}_{12} = C^{+}_{10}/\sqrt{2}, \quad S^{10}_{22} = C^{0}_{10},$$
$$S^{10}_{13} = S^{+}_{10}/\sqrt{2}, \quad S^{10}_{23} = S^{0}_{10}, \quad S^{10}_{33} = T^{0}_{10}. \tag{6a}$$

write as in CJ1 [12]

$$\mathfrak{B}_{\{ac\}b} = \delta^{\kappa}_{a}\delta^{\sigma}_{b}\delta^{\theta}_{c}B^{20'}_{\{\kappa\theta\}\sigma} + \frac{1}{\sqrt{2}}(\delta^{\kappa}_{a}\delta^{\sigma}_{b}\delta^{5}_{c} - \delta^{\kappa}_{c}\delta^{\sigma}_{b}\delta^{5}_{a})B^{10'}_{\kappa\sigma}$$

$$+ \frac{1}{\sqrt{6}}(2\delta^{\kappa}_{a}\delta^{5}_{b}\delta^{\sigma}_{c} + \delta^{5}_{a}\delta^{\kappa}_{b}\delta^{\sigma}_{c} - \delta^{\sigma}_{a}\delta^{\kappa}_{b}\delta^{5}_{c})B^{6'}_{\{\kappa\sigma\}}$$

$$+ \frac{1}{\sqrt{2}}(\delta^{\kappa}_{a}\delta^{5}_{b}\delta^{5}_{c} - \delta^{\kappa}_{c}\delta^{5}_{a}\delta^{5}_{b})B^{4'}_{\kappa}. \tag{5}$$

The above tensor is antisymmetric with respect to two indices within the curly bracket. The Greek indices run from 1 through 4. One of the tensors of the right hand side of the Eq. (5) has already been given in CJ1 (Eq. (7)). It is normalized to the particle number in the multiplet. For the sake of completeness, we give the expression again:

$$B^{20'}_{\{\mu\varrho\}\nu} = \delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{k}_{\varrho}N^{00}_{\{ik\}j} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{4}_{\varrho} - \delta^{i}_{\varrho}\delta^{j}_{\nu}\delta^{4}_{\mu})S^{10}_{ij}$$

$$+ \frac{1}{\sqrt{6}}(2\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{j}_{\varrho} + \delta^{4}_{\mu}\delta^{i}_{\nu}\delta^{j}_{\varrho} - \delta^{j}_{\mu}\delta^{i}_{\nu}\delta^{4}_{\varrho})T^{10}_{\{ij\}}$$

$$+ \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{4}_{\varrho} - \delta^{i}_{\varrho}\delta^{4}_{\nu}\delta^{4}_{\mu})T^{20}_{i}. \tag{5a}$$

Similarly for 10′, 6′, and 4′ representations we can derive the following expressions

$$B^{10'}_{\mu\nu} \doteq \delta^{i}_{\mu}\delta^{j}_{\nu}S^{01}_{ij} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu} + \delta^{i}_{\nu}\delta^{4}_{\mu})T^{11}_{i} + \delta^{4}_{\mu}\delta^{4}_{\nu}L^{21}, \tag{5b}$$

$$B^{6'}_{\{\mu\nu\}} = \delta^{i}_{\mu}\delta^{j}_{\nu}T^{01}_{\{ij\}} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu} - \delta^{i}_{\nu}\delta^{4}_{\mu})T^{11}_{i}, \tag{5c}$$

$$B^{4'}_{\mu} = \delta^{i}_{\mu}T^{02}_{i} + \delta^{4}_{\mu}L^{12}. \tag{5d}$$

In the above expressions i, j, and k are the SU(3) indices which run from 1 through 3. The tensor $B^{10'}_{\mu\nu}$ is totally symmetric whereas $B^{6'}_{\{\mu\nu\{}$ is totally antisymmetric with respect to the indices μ and ν. We introduce the following notation to designate the particles belonging to SU(3)-multiplets: a term $A^{mn}_{\dots}$ indicates to which multiplet the particles belong (for example if $A = N$, it belongs to the octet, if $A = S$ it belongs to the sextet and so on), and the suffixes m and n stand for the eigenvalues of C and C' respectively. We would follow Gaillard, Lee, and Rosner [14] for the identification of the particles. Thus for the sextet S^{10}_{ij} we would write

$$S^{10}_{11} = C^{++}_{10}, \quad S^{10}_{12} = C^{+}_{10}/\sqrt{2}, \quad S^{10}_{22} = C^{0}_{10},$$

$$S^{10}_{13} = S^{+}_{10}/\sqrt{2}, \quad S^{10}_{23} = S^{0}_{10}, \quad S^{10}_{33} = T^{0}_{10}. \tag{6a}$$

The totally symmetric representation $\underline{\underline{35}}$ can be described similarly by a tensor $\mathfrak{B}^{35}_{abc}$ (a, b, and c run from 1 through 5). If we express the representation in terms of $U(4)\otimes U_2$, we can write

$$\underline{\underline{35}} = (\underline{20}, 0)+(\underline{10}, 1)+(\underline{4}, 2)+(\underline{1}, 3). \tag{7}$$

The representation $\underline{20}$, $\underline{10}$, $\underline{4}$, and $\underline{1}$ can further be split up in terms of $SU(3)\otimes U_1$ contents as follows

$$\underline{20} = (10, 0)+(6, 1)+(3,2)+(1,3), \tag{7a}$$

$$\underline{10} = (6, 0)+(3,1)+(1, 2), \tag{7b}$$

$$\underline{4} = (3, 0)+(1, 1), \tag{7c}$$

$$\underline{1} = (1, 0). \tag{7d}$$

Hence the tensor $\mathfrak{B}^{35}_{abc}$ can now be expressed as

$$\mathfrak{B}^{35}_{abc} = \delta^{\mu}_{a}\delta^{\nu}_{b}\delta^{\varrho}_{c}B^{*20}_{\mu\nu\varrho}+\frac{1}{\sqrt{2}}(\delta^{\mu}_{a}\delta^{\nu}_{b}\delta^{5}_{c}+\delta^{5}_{a}\delta^{\mu}_{b}\delta^{\nu}_{c}+\delta^{\mu}_{a}\delta^{5}_{b}\delta^{\nu}_{c})B^{*10}_{\mu\nu}$$

$$+\frac{1}{\sqrt{3}}(\delta^{\mu}_{a}\delta^{5}_{b}\delta^{5}_{c}+\delta^{5}_{a}\delta^{\mu}_{b}\delta^{5}_{c}+\delta^{5}_{a}\delta^{5}_{b}\delta^{\mu}_{c})B^{*4}_{\mu}+\delta^{5}_{a}\delta^{5}_{b}\delta^{5}_{c}B^{*1}. \tag{8}$$

The tensor $\mathfrak{B}^{35}_{abc}$ is also normalized to the total number of particles in the multiplet. The expression $B^{*20}_{\mu\nu\varrho}$ is the same as Eq. (6) of CJ1. We reproduce it here for the sake of completeness with slightly extended nomenclature:

$$B^{*20}_{\mu\nu\varrho} = \delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{k}_{\varrho}d^{*00}_{ijk}+\frac{1}{\sqrt{3}}(\delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{4}_{\varrho}+\delta^{4}_{\mu}\delta^{i}_{\nu}\delta^{j}_{\varrho}+\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{j}_{\varrho})S^{*10}_{ij}$$

$$+\frac{1}{\sqrt{3}}(\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{4}_{\varrho}+\delta^{4}_{\mu}\delta^{4}_{\nu}\delta^{i}_{\varrho})T^{*20}_{i}+\delta^{4}_{\mu}\delta^{4}_{\nu}\delta^{4}_{\varrho}L^{*30}. \tag{8a}$$

The tensors $B^{*10}_{\mu\nu}$ and B^{*4}_{μ} are given by Eqs. (5b) and (5d) except that we have to replace the particle symbols S, T, and L by the corresponding resonances S^*, T^*, and L^*. All other suffixes remain unchanged. The particle identifications are as usual. d^{*00}_{ijk} is the normal decouplet. The sextet resonances are given by Eq. (6a), only inserting in addition an asterisk in each particle symbol. Similarly the triplets belonging to cogradient and contragradient representations are expressed by Eqs. (6c) and (6b) with the addition of an asterisk to each symbol. L^{*30} can be expressed by Eq. (6d) by inserting an asterisk. In Eq. (8) B^{*1} stands for

$$B^{*1} = L^{*03} = L^{*++}_{03}. \tag{8b}$$

The first part of Table III summarizes the nomenclature of $\underline{\underline{35}}$-representation.

The representation $\underline{\underline{10}}$ belonging to U(5) is totally antisymmetric in its indices and its composition in terms of $U(4)\otimes U_2$ breakdown is given by

$$\underline{\underline{10}} = (\bar{\underline{4}}, 0)+(\underline{6}'', 1), \tag{9}$$

TABLE III

Baryon identification in the following splitting scheme: U(5) → U(4)⊗U$_2$ → (SU(3)⊗U$_1$)⊗U$_2$ for $\underline{\underline{35}}$- and $\underline{\underline{10}}$-representation (*C*—*C′* model)

U(5) Rep.	*C′*	U(4) Rep.	*C*	SU(3) Rep.	Particles
$\underline{\underline{35}}$	0	$\underline{20}$	0	10	$N^{*++}, N^{*+}, Y^{*+}, N^{*0}, Y^{*0}, \Xi^{*0}$, $N^{*-}, Y^{*-}, \Xi^{*-}, \Omega^-$
			1	6	$C^{*++}_{10}, C^{*+}_{10}, S^{*+}_{10}, C^{*0}_{10}, S^{*0}_{10}, T^{*0}_{10}$
			2	3	$X^{*++}_{u20}, X^{*+}_{d20}, X^{*+}_{s20}$
			3	1	L^{*++}_{30}
	1	$\underline{10}$	0	6	$C^{*++}_{01}, C^{*+}_{01}, S^{*+}_{01}, C^{*0}_{01}, S^{*0}_{01}, T^{*0}_{01}$
			1	3	$X^{*++}_{u11}, X^{*+}_{d11}, X^{*+}_{s11}$
			2	1	L^{*++}_{21}
	2	$\underline{4}$	0	3	$X^{*++}_{u02}, X^{*+}_{d02}, X^{*+}_{s02}$
			1	1	L^{*++}_{12}
	3	$\underline{1}$	0	1	L^{*++}_{03}
$\underline{\underline{10}}$	0	$\underline{\bar{4}}$	0	1	$\bar{L}^{0}_{00}$
			1	$\bar{3}$	$\tilde{C}'^{+}_{10}, A'^{+}_{10}, A'^{0}_{10}$
	1	$\underline{6'}$	0	$\bar{3}$	$\tilde{C}'^{+}_{01}, A'^{+}_{01}, A'^{+}_{01}$
			1	3	$X'^{++}_{u11}, X'^{+}_{d11}, X'^{+}_{s11}$

where U(4) representations are expressed in SU(3)⊗U$_1$ composition as

$$\underline{\bar{4}} = (1, 0)+(\bar{3}, 1) \tag{9a}$$

$$\underline{6''} = (\bar{3}, 0)+(3, 1). \tag{9b}$$

The tensor representing the multiplet in the $\underline{\underline{10}}$-representation is given by

$$\mathfrak{B}^{10}_{\{abc\}} = \delta^{\mu}_{a}\delta^{\nu}_{b}\delta^{\varrho}_{c}B^{\bar{4}}_{\{\mu\nu\varrho\}} + \frac{1}{\sqrt{3}}(\delta^{\mu}_{a}\delta^{\nu}_{b}\delta^{5}_{c}+\delta^{5}_{a}\delta^{\mu}_{b}\delta^{\nu}_{c}-\delta^{\mu}_{a}\delta^{5}_{b}\delta^{\nu}_{c})B^{6''}_{\{\mu\nu\}}. \tag{10}$$

The U(4)-multiplets $B^{\bar{4}}_{\{\mu\nu\varrho\}}$ and $B^{6''}_{\{\mu\nu\}}$ can be expressed as follows:

$$B^{\bar{4}}_{\{\mu\nu\varrho\}} = \frac{1}{\sqrt{6}}\,\delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{k}_{\varrho}\varepsilon_{ijk}L^{00} + \frac{1}{\sqrt{3}}(\delta^{i}_{\mu}\delta^{j}_{\nu}\delta^{4}_{\varrho}+\delta^{4}_{\mu}\delta^{i}_{\nu}\delta^{j}_{\varrho}-\delta^{i}_{\mu}\delta^{4}_{\nu}\delta^{j}_{\varrho})T'^{10}_{\{ij\}} \tag{10a}$$

and

$$B^{6''}_{\{\mu\nu\}} = \delta^{i}_{\mu}\delta^{j}_{\nu}T'^{01}_{\{ij\}} + \frac{1}{\sqrt{2}}(\delta^{i}_{\mu}\delta^{4}_{\nu}-\delta^{i}_{\nu}\delta^{4}_{\mu})T'^{11}_{i}. \tag{10b}$$

In both U(4) and U(5) the tensors are normalized to the particle number in the multiplet. The $(\bar{3}, 1)$ components of $\underline{\bar{4}}$-multiplet expressed by the tensor $T'^{10}_{\{ij\}}$ in Eq. (10a) are given by Eq. (6b) with an additional prime attached to each particle. Thus for example

$T'^{10}_{\{23\}} = A'^{0}_{10}/\sqrt{2}$. The $(\bar{3}, 0)$ component of Eq. (9b) has been expressed by $T'^{01}_{\{ij\}}$ in Eq. (10b) and can also be designated by the particle identification of Eq. (6b) with additional primes. They are distinguished by C—C' values from the particles $T'^{10}_{\{ij\}}$ in Eq. (10a). We also retain the same symbol for L^{00} in Eq. (10a) as that of Eq. (6d). The second part of Table III expresses our choice of the nomenclature for $\underline{\underline{10}}$-representation.

3. *Most general currents and magnetic moment operators in U(5)*

By similar argument as shown is the reference CJ1, the most general current for $\underline{\underline{40}}$-representation is given by

$$J(\underline{\underline{40}})^{a'}_{a} = \mu_x \overline{\mathfrak{B}}^{\{a'c\}b} \mathfrak{B}_{\{ac\}b} + \mu_y \overline{\mathfrak{B}}^{\{cb\}a'} \mathfrak{B}_{\{ac\}b} + g_0 \delta^{a'}_{a} \langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{40}, \tag{11}$$

where

$$\langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{40} = \overline{\mathfrak{B}}^{\{dc\}b} \mathfrak{B}_{\{dc\}b}. \tag{11a}$$

Similarly for $\underline{\underline{35}}$-representation the most general current is given by

$$J(\underline{\underline{35}})^{a'}_{a} = \mu_0 \overline{\mathfrak{B}}^{a'bc} \mathfrak{B}_{abc} + g \delta^{a'}_{a} \langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{35} \tag{12}$$

where

$$\langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{35} = \overline{\mathfrak{B}}^{abc} \mathfrak{B}_{abc}. \tag{12a}$$

Also for totally antisymmetric representation $\underline{\underline{10}}$ of U(5) we obtain

$$J(\underline{\underline{10}})^{a'}_{a} = \mu_1 \overline{\mathfrak{B}}^{\{a'bc\}} \mathfrak{B}_{\{abc\}} + g_1 \delta^{a'}_{a} \langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{10} \tag{13}$$

where

$$\langle \overline{\mathfrak{B}} \mathfrak{B} \rangle_{10} = \overline{\mathfrak{B}}^{\{abc\}} \mathfrak{B}_{\{abc\}}. \tag{13a}$$

Assuming that the charge operator is

$$Q^{a}_{b} = q_b \delta^{a}_{b}, \tag{14}$$

where $q_1 = q_4 = q_5 = 2/3$ and $q_2 = q_3 = -1/3$ in C—C' model (see also Ref. [11]) and $q_1 = q_4 = 2/3$ and $q_2 = q_3 = q_4 = -1/3$ in the alternate model (Section 4), the expectation value of the magnetic moment operator is proportional to

$$J(X)^{a'}_{a} Q^{a}_{a'}, \tag{15}$$

where X stands for either $\underline{\underline{40}}$-, $\underline{\underline{35}}$- or $\underline{\underline{10}}$-representation.

A. $\underline{\underline{40}}$-representation

Using Eqs (5), (5a)—(5d), (11) and (15) we find the same results for the charmless and fancyless particles as in CJ1. For the sake of completeness we reproduce some of the results. For SU(3) baryon octet we have

$$\mu(\mathrm{p}) = \mu(\Sigma^+) = (1/6)\mu_x - (1/3)\mu_y + (2/3)g'_0, \tag{16a}$$

$$\mu(\mathrm{n}) = \mu(\Xi^0) = (1/6)\mu_x + (1/6)\mu_y + (2/3)g'_0, \tag{16b}$$

$$\mu(\Xi^-) = \mu(\Sigma^-) = -(1/3)\mu_x+(1/6)\mu_y+(2/3)g_0', \tag{16c}$$

$$\mu(\Lambda^0) = (1/12)\mu_x+(1/12)\mu_y+(2/3)g_0', \tag{16d}$$

$$\mu(\Sigma^0) = -(1/12)\mu_x-(1/12)\mu_y+(2/3)g_0'. \tag{16e}$$

The only difference between the results obtained in CJ1 and here is the fact that the constant $g_0' = 2g_0$ and does not change the main results obtained by Glashow and Coleman, or Okubo [15].

The nonvanishing transition moments for the octet are given by

$$\langle\Sigma^0|\mu|\Lambda^0\rangle = \langle\Lambda^0|\mu|\Sigma^0\rangle = -\frac{1}{4\sqrt{3}}(\mu_x+\mu_y). \tag{16f}$$

For the charmed baryons with fancy quantum number $C' = 0$, belonging to the sextet (6, 1) we get

$$\mu(C_{10}^{++}) = (2/3)\mu_x-(1/3)\mu_y+(2/3)g_0', \tag{17a}$$

$$\mu(C_{10}^{+}) = \mu(S_{10}^{+}) = (5/12)\mu_x-(1/12)\mu_y+(2/3)g_0', \tag{17b}$$

$$\mu(C_{10}^{0}) = \mu(S_{10}^{0}) = \mu(T_{10}^{0}) = \mu(\mathrm{n}). \tag{17c}$$

For the charmed baryon triplet (3,2) with $C' = 0$, we have

$$\mu(X_{u20}^{++}) = \mu(C_{10}^{++}), \tag{18a}$$

$$\mu(X_{d20}^{+}) = \mu(X_{s20}^{+}) = \mu(\mathrm{p}). \tag{18b}$$

For the charmed triplet $(\bar{3}, 1)$ with $C' = 0$, we get

$$\mu(C_{10}^{+}) = \mu(A_{10}^{+}) = (1/4)\mu_x-(1/4)\mu_y+(2/3)g_0', \tag{19a}$$

$$\mu(A_{10}^{0}) = -(1/6)\mu_x-(1/6)\mu_y+(2/3)g_0'. \tag{19b}$$

The transition moments between $C' = 0$ particles belonging to (6, 1) and $(\bar{3}, 1)$-representations remain also unchanged. The results are

$$-\langle\tilde{C}_{10}^{+}|\mu|C_{10}^{+}\rangle = -\langle C_{10}^{+}|\mu|\tilde{C}_{10}^{+}\rangle = \langle S_{10}^{+}|\mu|A_{10}^{+}\rangle = \langle A_{10}^{+}|\mu|S_{10}^{+}\rangle = \langle\Sigma^0|\mu|\Lambda^0\rangle. \tag{20}$$

Now for particles with $C' = 1$ belonging to $\underline{10}'$-representation, the sextet (6, 0) yields

$$\mu(C_{01}^{++}) = \mu(C_{10}^{++}), \tag{21a}$$

$$\mu(C_{01}^{+}) = \mu(S_{01}^{+}) = \mu(S_{10}^{+}), \tag{21b}$$

$$\mu(C_{01}^{0}) = \mu(S_{01}^{0}) = \mu(T_{01}^{0}) = \mu(\mathrm{n}). \tag{21c}$$

For the (3, 1), $C' = 1$ particles

$$\mu(X_{u11}^{++}) = \mu(C_{10}^{++}), \tag{22a}$$

$$\mu(X_{d11}^{+}) = \mu(X_{s11}^{+}) = \mu(S_{10}^{+}). \tag{22b}$$

For the singlet (1, 2) with $C' = 1$

$$\mu(L_{21}^{++}) = \mu(C_{10}^{++}). \tag{23}$$

The representation $\underline{6}'$ (see Eq. (4c)) with $C' = 1$ has a triplet $(\bar{3}, 0)$. The magnetic moments for those particles are given by

$$\mu(\tilde{C}_{01}^{+}) = \mu(A_{01}^{+}) = (17/36)\mu_x - (1/4)\mu_y + (2/3)g_0', \tag{24a}$$

$$\mu(A_{01}^{0}) = (1/18)\mu_x - (1/6)\mu_y + (2/3)g_0'. \tag{24b}$$

For the particles belonging to (3, 1) of $\underline{6}'$ with $C' = 1$, we have

$$\mu(\hat{X}_{u11}^{++}) = (8/9)\mu_x - (1/3)\mu_y + (2/3)g_0', \tag{25a}$$

$$\mu(\hat{X}_{d11}^{+}) = \mu(\hat{X}_{s11}^{+}) = \mu(\tilde{C}_{01}^{+}). \tag{25b}$$

The particles belonging to the $\underline{4}$-representation with $C' = 2$ possess magnetic moments under our assumption as follows:

For (3, 0)-representation we find

$$\mu(X_{u02}^{++}) = \mu(C_{10}^{++}), \tag{26a}$$

$$\mu(X_{d02}^{+}) = \mu(X_{s02}^{+}) = \mu(\mathrm{p}). \tag{26b}$$

For the singlet (1, 1) with $C' = 2$, we obtain

$$\mu(L_{12}^{++}) = \mu(C_{10}^{++}). \tag{27}$$

The nonvanishing transition moments between the particles belonging to $\underline{10}$- and $\underline{6}'$-representations are given by

$$-\langle C_{01}^{+}|\mu|\tilde{C}_{01}^{+}\rangle = \langle S_{01}^{+}|\mu|A_{01}^{+}\rangle = (1/3)\,\langle X_{u11}^{++}|\mu|\hat{X}_{u11}^{++}\rangle = (4/3)\,\langle X_{d11}^{+}|\mu|\hat{X}_{d11}^{+}\rangle$$
$$= (4/3)\,\langle X_{s11}^{+}|\mu|\hat{X}_{s11}^{+}\rangle = \langle \Sigma^{0}|\mu|\Lambda^{0}\rangle. \tag{28}$$

Here we must remember $\langle X|\mu|Y\rangle = \langle Y|\mu|X\rangle$.

B. $\underline{\underline{35}}$-representation

For the particles with $C' = 0$, the magnetic moments remain unchanged as in the $\underline{\underline{40}}$-representation. For the sake of completeness and slight modification of the nomenclature of the particles due to the introduction of the new quantum number C', we again quote some basic results already obtained earlier in CJ1.

For the decouplet particles belonging to (10, 0)-representation with $C' = 0$ we find

$$\mu(\mathrm{N}^{*++}) = (2/3)\mu_0 + (2/3)g', \tag{29a}$$

$$\mu(\mathrm{N}^{*+}) = \mu(\mathrm{Y}^{*+}) = (1/3)\mu_0 + (2/3)g', \tag{29b}$$

$$\mu(\mathrm{N}^{*0}) = \mu(\mathrm{Y}^{*0}) = \mu(\Xi^{*0}) = (2/3)g', \tag{29c}$$

$$\mu(\mathrm{N}^{*-}) = \mu(\mathrm{Y}^{*-}) = \mu(\Xi^{*-}) = \mu(\Omega^{-}) = -(1/3)\mu_0 + (2/3)g'. \tag{29d}$$

In the above equations we have set $g' = 2g$.

For the particles belonging to (6, 1)-representation with $C' = 0$

$$\mu(C_{10}^{*++}) = \mu(N^{*++}), \tag{30a}$$

$$\mu(C_{10}^{*+}) = \mu(S_{10}^{*+}) = \mu(N^{*+}), \tag{30b}$$

$$\mu(S_{10}^{*0}) = \mu(C_{10}^{*0}) = \mu(T_{10}^{*0}) = \mu(N^{*0}). \tag{30c}$$

For the particles belonging to (3,2) representation

$$\mu(X_{u20}^{*++}) = \mu(N^{*++}), \tag{31a}$$

$$\mu(X_{d20}^{*+}) = \mu(X_{s20}^{*+}) = \mu(N^{*+}). \tag{31b}$$

The magnetic moment for the singlet belonging to (1, 3) with $C' = 0$ is

$$\mu(L_{30}^{*++}) = \mu(N^{*++}). \tag{32}$$

For the particles belonging to the $\underline{10}$-representation with fancy quantum number $C' = 1$, we obtain the magnetic moments as follows:

For the particles within the (6, 0)-representation ($C' = 1$)

$$\mu(C_{01}^{*++}) = \mu(N^{*++}), \tag{33a}$$

$$\mu(C_{01}^{*+}) = \mu(S_{01}^{*+}) = \mu(N^{*+}), \tag{33b}$$

$$\mu(C_{01}^{*0}) = \mu(S_{01}^{*0}) = \mu(N^{*0}). \tag{33c}$$

For the particles within the (3, 1)-representation ($C' = 1$)

$$\mu(X_{u11}^{*++}) = \mu(N^{*++}), \tag{34a}$$

$$\mu(X_{d11}^{*+}) = \mu(X_{s11}^{*+}) = \mu(N^{*+}). \tag{34b}$$

For the singlet with $C' = 1$ and $C = 2$ we find

$$\mu(L_{21}^{*++}) = \mu(N^{*++}). \tag{35}$$

The particles which belong to the (3, 0)-representation of the multiplet $\underline{4}$ with $C' = 2$ yield the following results:

$$\mu(X_{u02}^{*++}) = \mu(N^{*++}), \tag{36a}$$

$$\mu(X_{d02}^{*+}) = \mu(X_{s02}^{*+}) = \mu(N^{*+}). \tag{36b}$$

For the (1, 1)-representation belonging to $\underline{4}$ with $C' = 2$, we have

$$\mu(L_{12}^{*++}) = \mu(N^{*++}). \tag{37}$$

For the singlet with $C = 0$ and $C' = 3$ we have

$$\mu(L_{03}^{*++}) = \mu(N^{*++}). \tag{38}$$

C. 10-representation

The particles belonging to $\underline{\underline{10}}$-representation expressed by the Eq. (9) has the $\bar{\underline{4}}$-component with $C' = 0$ and a sextet $\underline{6}''$ with $C' = 1$. Using Eqs. (10)—(10b) and the Eq. (13) we find for the $(\bar{3}, 1)$ component of the $\underline{4}$-representation

$$\mu(C'^{+}_{10}) = \mu(A'^{+}_{10}) = (1/3)\mu_1 + (2/3)g'_1, \tag{39a}$$

$$\mu(A'^{0}_{10}) = (2/3)g'_1 \tag{39b}$$

where we have set $g'_1 = 2g_1$. For the $(1, 0)$-component of the $\bar{\underline{4}}$-representation with $C' = 0$, we find

$$\mu(\bar{L}^{0}_{00}) = \mu(A'^{0}_{10}). \tag{40}$$

The moments for the particles belonging to the $\underline{6}''$-representation with $C' = 1$ are as follows: For triplet $(\bar{3}, 0)$ particles, we have

$$\mu(C'^{+}_{01}) = \mu(A'^{+}_{01}) = \mu(C'^{+}_{10}) \tag{41a}$$

$$\mu(A'^{0}_{01}) = \mu(A'^{0}_{01}). \tag{41b}$$

Similarly for $(3, 1)$-particles with $C' = 1$, we find

$$\mu(X'^{++}_{u11}) = (2/3)\mu_1 + (2/3)g'_1 \tag{42a}$$

$$\mu(X'^{+}_{d11}) = \mu(X'^{+}_{s11}) = \mu(C'^{+}_{10}). \tag{42b}$$

4. *Alternate model with f-quark having $Q = -1/3$*

Some authors [2] have indicated that the charge of the new quark f has shown some experimental bias for $Q = -1/3$. Although the justification of such conclusion is not completely overwhelming, we have nonetheless assumed the possibility that $Q = -1/3$ and studied whether this quark charge has any influence on the magnetic moments under the U(5)-symmetry. We have assigned the quantum numbers of f alternative values as follows: $Q = -1/3$, $Y = 4/3$, $B = 1/3$ and $C' = 1$. In contrast to the Eq. (1), we assume that the Gell-Mann–Nishijima formula takes the form

$$Q = I_3 + (Y/2) + C - C'. \tag{43}$$

With this assignment all unfancied particles remain unchanged. We retain the same nomenclature for the unfancied particles, we do however use for the fancied particles the same symbols with bold letters as given in Tables II and III, except that their charge assignment changes completely within a group. We have shown them in Table IV.

We can easily notice that in order to get the particles of $Q = -1/3$, with $C' = 1$ from $Q = 2/3$ assignment, we have merely to reduce the charge by one unit. For $C' = 2$, we have similarly to reduce the charge by two units. Thus for $C' = 1$, C^{++}_{01} of $Q = 2/3$ model belonging to $\underline{10}'$ of $\underline{\underline{40}}$-representation goes over to $\mathbf{C}^{+}_{01}$ in $Q = -1/3$ model. However $C' = 2$, $\underline{X}^{++}_{u02}$ of $\underline{4}$-representation belonging to $\underline{\underline{40}}$-representation for example changes to $\mathbf{X}^{0}_{u02}$. For the particle with $C' = 3$, the charge reduces by 3 units.

TABLE IV

Baryon identification in the following splitting scheme: U(5) → U(4)⊗U_2 → (SU(3)⊗U_1)⊗U_2 for 40-, 35-, and 10-representations for $C' \neq 0$ particles (alternate model)

U(5) Rep.	C'	U(4) Rep.	C	SU(3) Rep.	Particles
40	1	10′	0	6	$C^+_{01}, C^0_{01}, S^0_{01}, C^-_{01}, S^-_{01}, T^-_{01}$
			1	3	$X^+_{u11}, X^0_{d11}, X^0_{s11}$
			2	1	L^+_{21}
		6′	0	$\bar{3}$	$\tilde{C}^0_{01}, A^0_{01}, A^-_{01}$
			1	3	$\hat{X}^+_{u11}, \hat{X}^0_{d11}, \hat{X}^0_{s11}$
	2	4′	0	3	$\hat{X}^0_{u02}, \hat{X}^-_{d02}, \hat{X}^-_{s02}$
			1	1	L^0_{12}
35	1	10	0	6	$C^{*+}_{01}, C^{*0}_{01}, S^{*0}_{01}, C^{*-}_{01}, S^{*-}_{01}, T^{*-}_{01}$
			1	3	$X^{*+}_{u11}, X^{*0}_{d11}, X^{*0}_{s11}$
			2	1	L^{*+}_{21}
	2	4	0	3	$X^{*0}_{u02}, X^{*-}_{d02}, X^{*-}_{s02}$
			1	1	L^{*-}_{02}
	3	1	0	1	L^{*-}_{03}
10	1	6″	0	$\bar{3}$	$\tilde{C}'^0_{01}, A'^0_{01}, A'^-_{01}$
			1	3	$X'^+_{u11}, X'^0_{d11}, X'^0_{s11}$

A. 40-representation

When we replace in the calculation for magnetic moment the charge of the f-quark by $Q^5_5 = q_5 = -1/3$, we have found that all Eqs (16a)—(20) remain unchanged in so far as we replace the constants $g'_0 = 2g_0$ by $g''_0 = g_0/2$ and remember that for $C' = 0$, our particle nomenclatures remain the same. For $C' = 1$, and for particles belonging to the 10′-representation with nomenclature as in Table IV, we find for SU(3) sextet

$$\mu(C^+_{01}) = \mu(\text{p}), \tag{44a}$$

$$\mu(C^0_{01}) = \mu(S^0_{01}) = \mu(\Sigma^0), \tag{44b}$$

$$\mu(C^-_{01}) = \mu(S^-_{01}) = \mu(T^-_{01}) = \mu(\Sigma^-). \tag{44c}$$

For the SU(3) triplets belonging to the 10′-representation ($C' = 1$) we have

$$\mu(X^+_{u11}) = \mu(\text{p}), \tag{45a}$$

$$\mu(X^0_{d11}) = \mu(X^0_{s11}) = \mu(\Sigma^0). \tag{45b}$$

On the other hand for the singlet of the 10′-representation

$$\mu(L^+_{21}) = \mu(\text{p}). \tag{46}$$

Similarly for the $\underline{6}'$-representation with $C' = 1$ (see Table IV) we find

$$\mu(\tilde{C}^0_{01}) = \mu(A^0_{01}) = -(1/36)\mu_x+(1/12)\mu_y+(2/3)g''_0, \tag{47a}$$

$$\mu(A^-_{01}) = -(4/9)\mu_x+(1/6)\mu_y+(2/3)g''_0, \tag{47b}$$

$$\mu(X^+_{u11}) = (7/8)\mu_x+(2/3)g''_0, \tag{48a}$$

$$\mu(X^0_{d11}) = \mu(X^0_{s11}) = \mu(\tilde{C}^0_{01}). \tag{48b}$$

Finally for the particles belonging to the $\underline{4}$-representation we find for the f-quark charge $Q = -1/3$

$$\mu(X^0_{u02}) = \mu(L^0_{12}) = \mu(\mathrm{n}), \tag{49a}$$

$$\mu(X^-_{d02}) = \mu(X^-_{s02}) = \mu(\Sigma^-). \tag{49b}$$

B. $\underline{\underline{35}}$-representation

For particles belonging to the $\underline{20}$-representation with $C' = 0$ the magnetic moments stay unchanged (Eqs (29a)—(32)), except the constant $g' = 2g$ has to be replaced by $g'' = g/2$. For the representation $\underline{10}$ with $C' = 1$, we get

$$\mu(C^{*+}_{01}) = \mu(X^{*+}_{u11}) = \mu(L^{*+}_{21}) = (1/3)\mu_0+(2/3)g'', \tag{50a}$$

$$\mu(C^{*0}_{01}) = \mu(S^{*0}_{01}) = \mu(X^{*0}_{d11}) = \mu(X^{*0}_{s11}) = (2/3)g'', \tag{50b}$$

$$\mu(C^{*-}_{01}) = \mu(S^{*-}_{01}) = \mu(T^{*-}_{01}) = -(1/3)\mu_0+(2/3)g''. \tag{50c}$$

For particles with $C' = 2$ and belonging to the $\underline{4}$-representation we find

$$\mu(X^{*0}_{u02}) = \mu(L^{*0}_{12}) = \mu(C^{*0}_{01}), \tag{51a}$$

$$\mu(X^{*-}_{d02}) = \mu(X^{*-}_{s02}) = \mu(C^{*-}_{02}). \tag{51b}$$

Finally for the particle with $C' = 3$ and belonging to $\underline{1}$-representation we get

$$\mu(L^{*-}_{03}) = \mu(C^{*-}_{01}). \tag{52}$$

For the new nomenclature of the particles we must not forget to compare the notations in Table IV.

C. $\underline{\underline{10}}$-representation

In this representation particles with $C' = 0$ stay unchanged. We can use the Eqs (39a)—(40) with the modification that $g'_1 = 2g_1$ must be replaced by $g''_1 = g_1/2$.

For the particles with $C' = 1$ and belonging to the $\underline{6}''$-representation

$$\mu(\tilde{C}'^0_{01}) = \mu(A'^0_{01}) = \mu(X'^0_{s11}) = (2/3)g'', \tag{53a}$$

$$\mu(A'^-_{01}) = -(1/3)\mu_1+(2/3)g''_1, \tag{53b}$$

$$(X\mu'^+_{u11}) \;||(1/3)\mu_1+(2/3)g''_1. \tag{53c}$$

5. *Concluding remarks*

We have extended the U(4)-model by introducing another quark, first according to the prescription of the C—C′ model of Achiman, Kollar and Walsh and then slightly modifying the model by changing the f-quark charge to $-1/3$. Then assuming that the magnetic moment operator transforms as charge operator, we obtain the magnetic moments of the baryon in the U(5)-symmetry. The magnetic moment results of all particles, which show up in U(4)-symmetry, have been found to remain unchanged, which is not at all a surprising result. The magnetic moments of new particles, which should show up if the quark model is the true description of the baryon composition can be expressed in terms of the moments of some particles in the U(4)-symmetry.

As we have mentioned earlier, we have discussed both cases of the charge for the f-quark, i.e., $Q = 2/3$ and $Q = 1/3$ and $Q = -1/3$ separately. The reason for doing so is the fact, that in Y-spectroscopy, according to several authors the second charge choice might be experimentally favored, although it is not completely certain. The discovery of further meson and baryon states will clarify the situation.

As a natural extension, we have enlarged the U(5)-symmetry to U(10) to incorporate intrinsic spin as we have done in the SU(8)-symmetry (CJ2, [12]). In the second part of this paper we would give the results obtained for the U(10)-symmetry.

REFERENCES

[1] S. W. Herb et al., *Phys. Rev. Lett.* **39**, 252 (1977).
[2] C. E. Carlson, R. Suaya, *Phys Rev. Lett.* **39**, 908 (1977); D. B. Lichtenberg et al., *Phys Rev. Lett.* **39**, 1592 (1977); C. H. Albright et al., Fermilab preprint, Fermilab-Pub-77/81 — Thy (1977).
[3] J. J. Aubert et al., *Phys. Rev. Lett.* **33**, 1404 (1974); J.-E. Augustin et al., *Phys. Rev. Lett.* **33**, 1406 (1974); C. Bacci et al., *Phys. Rev. Lett.* **33**, 1408 (1974).
[4] See for example A. De Rújula, *The Weak Current*, Review based on Les Houches Summer School Talk (1976) — HUTP-77/AOO6 (1977).
[5] S. L. Glashow, J. Iliopoulos, L. Maiani, *Phys. Rev.* **D2**, 1285 (1970).
[6] H. Harari, *How many quarks are there?*, Weizmann Institute of Science preprint, WIS- 76/43 — Ph (1976).
[7] See for example J. D. Bjorken, *Weak Interaction Theory and Neutral Currents*, SLAC PUB 1866 (1977).
[8] H. Harari, *Phys Lett.* **57B**, 265 (1975); *Ann. Phys.* (USA) **94**, 391 (1975).
[9] M. Barnett, *Phys. Rev. Lett.* **36**, 1163 (1976).
[10] Y. Achiman, K. Kollar, T. F. Walsh, *Phys. Lett.* **59B**, 261 (1975). For similar model see also S. Ono, *States of Hadrons with Five Quarks*, UC-Davis preprint (1977).
[11] A. L. Choudhury, *Acta Phys. Pol.* **B8**, 989 (1977).
[12] A. L. Choudhury, V. Joshi, *Phys. Rev.* **D13**, 3115 (1976). This paper would be quoted as CJ1 in the text; *Phys. Rev.* **D13**, 3120 (1976), to be quoted as CJ2 in the text. *Phys. Rev.* **D14**, 2437 (E) (1977).
[13] D. B. Lichtenberg, *Phys. Rev.* **D15**, 345 (1977); R. J. Johnson, M. Sah-Jahan, *Phys. Rev.* **D15**, 1400 (1977).
[14] M. K. Gaillard, B. W. Lee, J. L. Rosner, *Rev. Mod. Phys.* **47**, 227 (1975).
[15] S. Coleman, S. L. Glashow, *Phys. Rev. Lett.* **6**, 423 (1961); S. Okubo, *Prog. Theor. Phys.* **27**, 949 (1962); *Phys. Lett.* **4**, 14 (1963).