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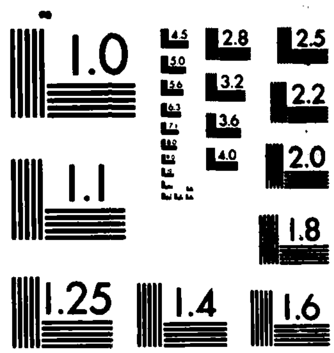

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FOREIGN TECHNOLOGY DIVISION

AN SU(6) GRAND UNIFIED MODEL

by

J. Xiang Dong

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An SU(6) Grand Unified Model*

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ABSTRACT

A model of grand unified theory based on SU(6) gauge group is proposed. It can accommodate two generations of ordinary fermions with V-A weak coupling and two generations of weird fermions with V+A weak coupling. In this model a new discrete symmetry is introduced which insures existence of fermions with lower masses when SU(6) gauge symmetry is spontaneously broken. We choose simple Higgs fields with appropriate vacuum expectation values so that the masses of weird fermions are heavier than those of ordinary fermions. This model also gives the same value of Weinberg angle, $\sin^2\theta_W = 3/8$, as in the usual SU(5) grand unified model at the grand unified scale.

I. Introduction

Due to the success of the Glashow-Weinberg-Salam's unified model for the weak and electromagnetic interactions and the support of the QCD theory [1] by three kinds of experiments, people have great confidence in the construction of gauge theory. Recently, a lot of grand unified gauge models for the strong, weak, and electromagnetic interactions have been proposed. Among those models, SU(5) [2] and SO(10) [3] are the simplest. Although these two models are elegant,

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they repeatedly fill same representation with three generations of fermions. In other words, they don't solve the problem of generations unification. Because of this, the unified theory of generations has been investigated intensively since then. According to Georgi's three principles [4] for the construction of the SU(N) model, only SU(11) and SU(14) models are able to accommodate three or more generations of fermions. Since a lot of particles will appear on these high order group models, some other new methods have been thus proposed to construct a low order group model. One of these methods [5] is to change the mechanism of spontaneous symmetry breakdown.

In this paper the SU(5) model is expanded by a simple method and a most economical SU(6) grand unified model is constructed. Since the fermion representation of SU(6) is a real representation, according to the "survival hypothesis" proposed by Georgi [4], the fermion will obtain the mass in the order of 10^{15} Gev. This almost denies the possibility to employ the SU(6) model of the Higgs's broken mechanism.

Here we will employ a discrete symmetry which was first introduced in Ref.6. Under this symmetry, the fermions obtain mass when the symmetry is broken in the 10^{2} Gev energy scale but not in the 10^{15} Gev energy scale. This will thus solve the problem we mentioned above. These two kinds of symmetry breakings can be achieved in this paper by choosing appropriate Higgs fields and their vacuum expectation values.

After avoiding the problem of repeatedly filling a same representation with generations of fermions, the SU(6) model can accommodate two generations of ordinary fermions with left-handed weak current and two generations of weird fermions with right-handed weak current.So farthe latter case is not observed by experiment. From the point of view of theory, this implies that the mass of the last two generations of fermions must be much larger than the mass of the first two generations of fermions.

In this paper, a set of Higgs fields with simple forms and their vacuum expectation values are chosen such that the mass of the ordinary fermions and the weird fermions can be separated. For the two generations of weird fermions, a few tens of Gev or more than one hundred of Gev of mass can be obtained. For the two generations of ordinary fermions, however, a lower mass is obtained.

If a high dimension Higgs field is introduced, it is very complicated to solve the minimun self-interaction energy of the Higgs field.[7] No further discussion about this will be given in this paper.

II. The Filling of the Lepton and Quark

The leptons and quarks are filled into five completely antisymmetry representations of SU(6):

$$\psi_{iR} = \underline{6}_R, \quad \psi_{ijL} = \underline{15}_L, \quad \psi_{ijkR} = \underline{20}_R,$$
$$\psi_{ijklL} = \underline{15}^*_L, \quad \psi_{ijklmR} = \underline{6}^*_R$$

where L and R represent left hand and right hand, i,j,k,l,m = 1,2,3,4,5,6. By this way, the ABJ anticonstants will be cancelled out by each other and the theory can be rearranged.

The five representations above of SU(6) can be decomposed according to SU(5). They are:

$$21_R, \underline{5}_R, \underline{5}^*_R, \underline{5}_L, \underline{5}^*_L, \underline{10}_R, \underline{10}^*_R, \underline{10}_L, \underline{10}^*_L.$$

Two generations of ordinary leptons and quarks are filled into $\underline{5}_R$, $\underline{10}_L$, and $\underline{5}^*_L$, $\underline{10}^*_R$, respectively. Two generations of weird leptons and quarks are filled into $\underline{5}_L$, $\underline{10}_R$ and $\underline{5}_R^*$, $\underline{10}_L^*$, respectively. Here ξ, ν_ξ and ξ', ν_ξ' represent two generations of weird leptons, and g, h and g', h' represent two generations of weird quarks. The neutral particles N_1 and N_2 are also filled into two $\underline{1}_R$ representations. The complete filling is shown below:

$$\underline{5}_R = \begin{vmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{vmatrix}_R = \begin{vmatrix} d_1 \\ d_2 \\ d_3 \\ e^c \\ \nu_e^c \end{vmatrix}_R ,$$

$$\underline{10}_L = \begin{vmatrix} 0 & 12 & 13 & 14 & 15 \\ & 0 & 23 & 24 & 25 \\ & & 0 & 34 & 35 \\ & & & 0 & 45 \\ & & & & 0 \end{vmatrix}_L = \frac{1}{\sqrt{2}} \begin{vmatrix} 0 & c_3^c & -c_2^c & u_1 & d_1 \\ & 0 & c_1^c & u_2 & d_2 \\ & & 0 & u_3 & d_3 \\ & & & 0 & e^c \\ & & & & 0 \end{vmatrix}_L$$

$$\underline{5}_L^* = \begin{vmatrix} 2345 \\ 1345 \\ 1245 \\ 1235 \\ 1234 \end{vmatrix}_L = \begin{vmatrix} s_1^c \\ -s_2^c \\ s_3^c \\ \mu^- \\ \nu_\mu \end{vmatrix}_L ,$$

$$\underline{10}_R^* = \begin{vmatrix} 0 & 345 & 245 & 235 & 234 \\ & 0 & 145 & 135 & 134 \\ & & 0 & 125 & 124 \\ & & & 0 & 123 \\ & & & & 0 \end{vmatrix}_R = \frac{1}{\sqrt{2}} \begin{vmatrix} 0 & u_3 & u_2 & c_1^c & s_1^c \\ & 0 & u_1 & -c_2^c & -s_2^c \\ & & 0 & c_3^c & s_3^c \\ & & & 0 & \mu \\ & & & & 0 \end{vmatrix}_R$$

$$\underline{5}_L = \begin{vmatrix} 16 \\ 26 \\ 36 \\ 46 \\ 56 \end{vmatrix}_L = \begin{vmatrix} g_1 \\ g_2 \\ g_3 \\ \xi^c \\ \nu_\xi^c \end{vmatrix}_L ,$$

$$\underline{10}_R = \begin{vmatrix} 0 & 126 & 136 & 146 & 156 \\ & 0 & 236 & 246 & 256 \\ & & 0 & 346 & 356 \\ & & & 0 & 456 \\ & & & & 0 \end{vmatrix}_R = \frac{1}{\sqrt{2}} \begin{vmatrix} 0 & h_3^c & -h_2^c & h_1 & g_1 \\ & 0 & h_1^c & h_2 & g_2 \\ & & 0 & h_3 & g_3 \\ & & & 0 & \xi^c \\ & & & & 0 \end{vmatrix}_R$$

$$\begin{vmatrix} 23456 \\ 13456 \end{vmatrix} \quad \begin{vmatrix} g_1'^c \\ -g_2'^c \end{vmatrix}$$

$$\underline{5}_R^* = \begin{vmatrix} 12456 \\ 12356 \\ 12346 \end{vmatrix}_R = \begin{vmatrix} g_3'^c \\ \xi' \\ \nu_{\xi'} \end{vmatrix}_R .$$

$$\underline{10}_L^* = \begin{vmatrix} 0 & 3456 & 2456 & 2356 & 2346 \\ & 0 & 1456 & 1356 & 1346 \\ & & 0 & 1256 & 1246 \\ & & & 0 & 1236 \\ & & & & 0 \end{vmatrix}_L = \frac{1}{\sqrt{2}} \begin{vmatrix} 0 & h_3' & h_2' & h_1'^c & g_1'^c \\ & 0 & h_1' & -h_2'^c & -g_2'^c \\ & & 0 & h_3'^c & g_3'^c \\ & & & 0 & e' \\ & & & & 0 \end{vmatrix}_L$$

$$1_R = (0)_R = N_{1R}, \quad 1_R = (12345)_R = N_{2R}$$

In the above expressions, $\psi^c = C\bar{\bar{\psi}}$ and $C = i r_2 r_4$ are the charge conjugation operators. The r_5 matrix is

$$r_5 = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}.$$

Since the charge operator is a generating element of SU(6), so TrQ = 0, i.e. the total charge of all the particles which belong to each irreducible representation is equal to zero. For $\underline{6}_R$, there are

$$3Q_d + Q_{e^c} = 0$$

$$Q_d = -\frac{1}{3} Q_{e^c} = -\frac{1}{3} e$$

Here the Q operator is:

$$Q = \begin{vmatrix} -\frac{1}{3} & & & & & \\ & -\frac{1}{3} & & & 0 & \\ & & -\frac{1}{3} & & & \\ & & & 1 & & \\ & 0 & & & 0 & \\ & & & & & 0 \end{vmatrix} = -\sqrt{\frac{2}{3}}\, T_{15}$$

where T_{15} is a diagonal generating element of SU(6). For more detail about the generating elements of SU(6), please see the "Chinese Science" paper in Ref.5.

The hypercharge operator Y, which is corresponding to the U(1) transformation, has the following expression:

$$Y = \begin{vmatrix} -\frac{1}{3} & & & & & \\ & -\frac{1}{3} & & & 0 & \\ & & -\frac{1}{3} & & & \\ & & & \frac{1}{2} & & \\ & 0 & & & \frac{1}{2} & \\ & & & & & 0 \end{vmatrix}$$

The hypercharge Y is related to the charge Q and the third component of weak isospin I_3 by:

$$Y = Q - I_3$$

III. The Broken Mechanism of Symmetry

According to the "survival hypothesis", when SU(6) symmetry is first breaking into SU(3)xSU(2)xU(1) through the Higgs mechanism, the fermions will obtain the mass in the order of 10^{15} Gev. In order to solve this problem, we introduce a discrete symmetry which was proposed in Ref.6.

The Lagrangian is assumed to be invariant under the discrete symmetry S which is defined below.

$$\psi_L \rightarrow i\psi_L, \quad \psi_R \rightarrow -i\psi_R$$
$$A_\mu \rightarrow A_\mu, \quad \chi \rightarrow \chi, \quad \phi \rightarrow -\phi$$

where ψ_L represents ψ_{ijL} or ψ_{ijklL} ; ψ_R represents ψ_{iR} , ψ_{ijkR} , or ψ_{ijklmR} . A_μ is a gauge field. χ and ϕ are two kinds of Higgs fields. They all belong to the irreducible representations of the grand unified group SU(6). Their vacuum expectation values are:

$$\langle \chi \rangle \sim 10^{15} \text{ Gev}, \quad \langle \phi \rangle \sim 10^{2} \text{ Gev}.$$

It is obvious that when the Lagrangian is invariant under the SU(6)xS symmetry, χ can not couple with the fermion field into a mass invariant term of SU(6)xS. Therefore, in this symmetry breaking of 10^{15} Gev, the fermions can not obtain large mass.

The first symmetry break is: $SU(6) \times S \xrightarrow{KVB \sim 10^{15}GeV} SU(3)_c \times SU(2)_L \times U(1)_Y \times S$. This can be achieved by introducing the Higgs field χ_i of the adjoint representation and the Higgs field χ_i of the fundamental representation. Their vacuum expectation values are:

$$\langle \chi_i^j \rangle = \begin{vmatrix} -\frac{2}{3} & & & & & \\ & -\frac{2}{3} & & & 0 & \\ & & -\frac{2}{3} & & & \\ & 0 & & 1 & & \\ & & & & 1 & \\ & & & & & 0 \end{vmatrix} a, \qquad \langle \chi_i \rangle = \begin{vmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ b \end{vmatrix}$$

where $a, b \sim 10^{12}$ Gev.

The second symmetry break is: $SU(3)_c \times SU(2)_L \times U(1)_Y \times S \xrightarrow{EVE \sim 10^2 GeV} SU(3)_c \times U(1)$. In this stage, a six-dimension Higgs field Φ is introduced, and its vacuum expectation value is chosen as

$$\langle \phi_i \rangle = \begin{vmatrix} 0 \\ 0 \\ 0 \\ 0 \\ v \\ 0 \end{vmatrix} \qquad v \sim 10^2 \text{ GeV}$$

In this broken stage, the fermions will obtain mass.

IV. The Mass of the Fermions

1. The Mass of the Weird Fermions

In the previous representations, they were filled by two generations of the ordinary fermions and two generations of the weird fermions. So far the latter case is not observed by experiments. In order to solve this problem, we try to find an appropriate Higgs field such that, after the second broken stage, the mass of the weird fermions will increase but the mass of the ordinary fermions remains the same.

If only the zeroth order approximation and two generations of weird fermions are considered, we can achieve our goal by choosing the

Higgs fields of Φ^{k}_{ij} and Φ^{lm}_{ijk} and their vacuum expectation values as below:

$$
\begin{aligned}
\langle\phi^{1}_{15}\rangle &= \langle\phi^{2}_{25}\rangle = \langle\phi^{3}_{35}\rangle = f, \quad \langle\phi^{4}_{45}\rangle = -3f, \\
\langle\phi^{1}_{14}\rangle &= \langle\phi^{2}_{24}\rangle = \langle\phi^{3}_{34}\rangle = w, \\
\langle\phi^{1}_{34}\rangle &= \langle\phi^{2}_{34}\rangle = \langle\phi^{4}_{44}\rangle = [illegible]w, \\
\langle\phi^{1n}_{516}\rangle &= \langle\phi^{2n}_{526}\rangle = \langle\phi^{3n}_{536}\rangle = -w
\end{aligned}
$$

$\langle \Phi^{4l}_{5+6} \rangle = 3w$, and the rest of terms are zero. If we let $f \sim w \sim 10^{2}$ Gev, our expectation can be satisfied through the following Yukawa coupling:

$$
\begin{aligned}
& C_1 \bar{\psi}^{ij}_{L} \langle\phi^{k}_{ij}\rangle \psi_{Rk} = C_1 f(\bar{d}_L d_K - 3\bar{e}_L e_K) \\
& \frac{C_2}{2} \bar{\psi}^{ijkl}_{L} \langle\phi^{m}_{ij}\rangle \psi_{Rklm} = C_2 f(3\bar{\mu}_L\mu_R - \bar{s}_L s_K - 2\bar{h}_L h'_K + 2\bar{h}'_L h_K) \\
& \frac{C_3}{3!} \bar{\psi}^{ijkl}_{L} \langle\phi^{lmn}_{ij}\rangle \psi_{Kijkmn} = C_3 f^*(\bar{g}'_L g'_K - 3\bar{\xi}'_L \xi'_K) \\
& C_4 \bar{\psi}^{ij}_{L} \langle\phi^{+kl}_{i}\rangle \psi_{Rjkl} = C_4 f^*(2\bar{u}_L u_R - 2\bar{c}_L c_K + \bar{g}_L g_R - 3\bar{\xi}_L \xi_K) \\
& D_1 \bar{\psi}^{ij}_{L} \langle\phi^{+klm}_{ij}\rangle \psi_{Kklm} = D_1 w^*(-\bar{u}_L u_K + \bar{c}_L c_K + \bar{g}_L g_K - 3\bar{\xi}_L \xi_K) \\
& D_2 \bar{\psi}^{ijkl}_{L} \langle\phi^{mn}_{ijk}\rangle \psi_{Klmn} = D_2 w(\bar{s}_L s_K - 3\bar{\mu}_L\mu_K - \bar{h}_L h'_K + \bar{h}'_L h_K)
\end{aligned}
$$

where C_1, C_2, C_3, C_4 and D_1, D_2 are the Yukawa coupling constants. For simplicity, only the real values are taken for the vacuum expectation values. When we choose $f=w$, $C_1=0$, $C_2=D_2$, and $2C_4=D_1$, we will get:

$$
\begin{aligned}
m_{\xi} &= 9C_4 f \quad & m_g &= 3C_4 f \quad & m_s &= 3C_2 f \\
m_{\xi'} &= 3C_3 f \quad & m_{g'} &= C_3 f \quad & m_{h'} &= 3C_2 f
\end{aligned}
$$

It can be seen that only the weird fermions can obtain mass. If f is chosen to be in the order of 300 Gev, and the coupling constants are chosen to be in the order of 10^{-1}, then the masses of these heavy fermions can be as high as several tens of Gev.

2. The Mass of the Ordinary Fermions

The mass of the weird fermions can be increased as described in the previous subsection. If we consider the masses of all the fermions, then we should choose the following Yukawa coupling of the six-dimension Higgs field of Section III.

$$A_1\bar{\psi}_L^{ij}\langle\phi_i\rangle\psi_{Rj} = A_1 v(-\bar{e}_L e_R - \bar{d}_L d_R + \bar{\nu}_{\xi L} N_{1R})$$

$$\frac{A_2}{3!}\bar{\psi}_L^{ijkl}\langle\phi_l\rangle\psi_{Rijk} = A_2 v(\bar{\mu}_L\mu_R + \bar{s}_L s_R - \bar{h}_L h'_R - \bar{h}'_L h_R)$$

$$\frac{A_3}{2}\bar{\psi}_L^{ij}\langle\phi^{*k}\rangle\psi_{Rijk} = A_3 v^*(\bar{u}_L u_R + \bar{c}_L c_R - \bar{\xi}_L\xi_R - \bar{g}_L g_R)$$

$$\frac{A_4}{4!}\bar{\psi}_L^{ijkl}\langle\phi^{*m}\rangle\psi_{Rijklm} = A_4 v^*(-\bar{\xi}'_L\xi'_R - \bar{g}_L g'_R + \bar{\nu}_{\mu L} N_{2R})$$

Here, we let the previous $C_1 \neq 0$, and let $v = v^* = f$, $A_1 = -2C_1$, $A_4 = 0$. By this way, the eigenvalues of the four generations of particle masses are:

$$\begin{array}{lll}
m_e = C_1 v & m_d = 3C_1 v & m_u = A_1 v \\
m_\mu = A_2 v & m_s = A_2 v & m_c = A_3 v \\
m_\xi = (A_3 + 9C_4)v & m_g = (3C_4 - A_3)v & m_h = (3C_4 + A_4)v \\
m_{\xi'} = 3C_4 v & m_{g'} = C_4 v & m_{h'} = (3C_4 - A_2)v \\
m_{\nu_1} = m_{\nu_\xi} = -C_1 v, & m_{\nu_e} = m_{\nu_\mu} = m_{\nu_{\xi'}} = m_{\nu_2} = 0 &
\end{array}$$

These expressions for the masses of ordinary fermions are not too good. If we choose a two-step antisymmetry Higgs field Φ_{ij}, let $\langle\Phi_{54}\rangle = v$, and adjust the coupling constants of the mass eigenvalues, then the values of m_s and m_μ, or m_u and m_c can be separated. However, the mass expressions in this case will become very complicated. These expressions will not be shown in this paper.

In our theory, there exists particle N_{2R} with zero mass. This particle is a singlet of SU(5). So it does not participate in the strong, electromagnetic, and weak interactions, and only couples with the gauge field in the grand unified mass scale. But it does not couple with the Higgs field particles. Therefore, it is very hard to be detected in the experiment.

In our model, the derived $\sin^2\theta_W$ value at the grand unified energy scale is 3/8. This is the same as the value derived from the usual grand unified model SU(5). Besides, the rearrangment of $\sin^2\theta_W$ is also the same as that in the SU(5) model. No further discussion about this will be presented here.

In summary, an additional discrete symmetry is employed in this paper such that an SU(6) grand unified model is constructed. This model accommodates two generations of (V-A) ordinary fermions and two generations of (V+A) weird fermions. By choosing an appropriate Higgs mechanism, the mass of the ordinary fermions and the mass of the weird fermions can be separated.

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REFERENCES

[1] Du, Dong-Shen, Proceeding of the Hadron Structure Conference at Wuhan, 1980, "Grand Unified Theory", p.150.

[2] Georgi,H. & Glashow, S.L. ibid., 32(1974),438.

[3] Pati,J.C. & Salam,A. Phys. Rev. D10(1974),275; Fritzsch,H. & Minkowski.P. Ann. Phys. 93(1975),193; Nucl. Phys. B103(1976),61; Georgi,H., Particles and Fields, 1974 (APS/DPF Williamsburg), ed. C.E. Carlson, AIP, New York, 1975, p.575; Glashow,S.L., HUTP 77/A005 (1977).

[4] Georgi,H., Nucl. Phys. B156(1979),126.

[5] P.Langacker, G.Segre and A.Weldon, Phys. Lett. 73B(1978),87; Phys. Rev. D18(1978),552; M.Abud, F.Buccella, H.Ruegg and C.A.Savoy, Phys. Lett. 67B(1977),313; M.Yoshimura, Prog. Theor. Phys. 58(1977),972; H.Georgi and A.Pais Phys. Rev. D19(1979),2746; K.Inone,A.Kakuto, H.Komatsu and Y.Nakano, Prog. Theor. Phys. 58(1977),1901,1914; S.K.Yun, Phys.Rev. D18(1978), 3472. Int. J. Math. Phys. 18(1979),359; J.E.Kim, Phys. Lett. 107B(1981),69.
Ma,Zhong-Qi, Du,Dong-Shen, Yue,Zong-Wu, and Xue,Pi-You, Chinese Science,4(1981), 415.

[6] Ma,Zhong-Qi, Du,Dong-Shen, Xue,Pi-You, Chinese Science, 11(1981), 1322.

[7] Gao,Chong-Shou, 1982 HangZhou Conference, "Some Discussion About The SU(N) Grand Unified Structure".
J.S.Kim, Nucl. Phys. B196(1982),285.

AN *SU* (6) GRAND UNIFIED MODEL

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Abstract

A model of grand unified theory based on $SU(6)$ gauge group is proposed. It can accommodate two generations of ordinary fermions with $V-A$ weak coupling and two generations of anomalous fermions with $V+A$ weak coupling. In this model a new discrete symmetry is introduced which insures existence of fermions with lower masses when $SU(6)$ gauge symmetry is spontaneously broken. We choose simple Higgs fields with appropriate vacuum expectation values so that the masses of anomalous fermions are heavier than those of ordinary fermions. This model also gives the same value of Weinberg angle, $\sin^2\theta_w = \frac{3}{8}$, as in the usual $SU(5)$ grand unified model at the grand unified scale.

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