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A New Scenario of Composite Model for Quarks and Leptons

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ABSTRACT

A new scenario of composite model for quarks and leptons is proposed. There are two kinds of fermionic preons, named X and Y, with four "valencies" and two kinds bosonic preons, named α and β, with zero "valencies". Based on the topological and space properties of compositeness, three generations of left hand doublet quarks and leptons are obtained. In our model, quark and lepton have different topology. From the view of topological properties, space constructure and preon's bound of compositeness, a possible new idea of the standard $SU(3)_c \times SU(2) \times U(1)$ theory are given. $SU(3)_c$ interaction may be explained as residual forces of the Van de Waals interaction; $SU(2)$ weak isospin symmetry looks like to the permutation symmetry of preons X and Y; $U(1)$ interaction, *i.e.*, the charge of quarks and leptons not only come from the charge of preons, but also depends on the topological properties. The intermediate bosons $W^{\pm}$, Z° and Higgs particles in the standard model are also probably composite objects.

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It is known that there exist the following three generations of quarks and leptons

$$\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L$$

$$\begin{pmatrix} u_i \\ d_i \end{pmatrix}_L \begin{pmatrix} c_i \\ s_i \end{pmatrix}_L \begin{pmatrix} t_i(?) \\ b_i \end{pmatrix}_L ; e_R, \mu_R, \tau_R, u_{iR}, d_{iR}, c_{iR}, s_{iR}, t_{iR}(?), b_{iR} \qquad (.1)$$

where $i = 1, 2, 3$ is color index.

How do you explain the existence of three generations of quarks and leptons. How do you explain the observed pattern within each generation. This is a motivation for considering composite models of quarks and leptons. From the view of dynamics, in the standard $SU(3) \times SU(2) \times U(1)$ low energy theory, there are a lot of parameters which are put in by hand. It is also hard to believe that all of these leptons and quarks, which obey the $SU(3) \times SU(2) \times U(1)$ theory, are elementary.

In fact, many physicists believe the existence of more fundamental particles, preons, which are building-blocks of these leptons and quarks.[1] Recently, people also suggest that scalar Higgs particles and intermediate bosons $W^{\pm}$, Z° are probably composite objects.[2]

For the last several years, numerous interesting ideas of quark-lepton constructure and many subquark models have been proposed and discussed. In the proposed composite models and mechanism for compositeness, the main methods of building-blocks of leptons and quarks apply the idea of atomic, nuclei and nucleon structure. For example, we assume that we have a set of fundamental preons (fermions or bosons) and there is a new fundamental color-like (hyper-color interaction) interaction which is responsible for binding the preons within a quark or a lepton. It just does like that the atom consists of electrons and nucleus bound by the electromagnetic interaction, the nuclei consists of nucleons bound by nuclei force and so on. Now, in the subquark models, quarks and leptons are put in the same level in general. So there is a problem about origin of flavors and colors which are only for quarks. Especially, we need to explain quark's colors, but the lepton's lack of color. In some of the composite models of quarks and leptons proposed so far, it is assumed that the flavor of a lepton or the flavor and color of a quark come from that of the constituent preons, i.e., we assume that preons have color quantum number, generation quantum number (*i.e.*, the horizontal symmetry of the generations is assumed) and weak-isospin quantum number. For example, Terazawa[3] assume that each one of preons has only one of these quantum number and, therefore, has only one function. The problem is that the number of preons with different quantum number is often larger than the total number of known quarks and leptons. From the well-established facts of matter constructure, it is hard to believe that the number of "constituent block" is larger than that of composite matter. People do like to believe that many many composite matter (for example the atoms) consist of a few fundamental constituents (electrons and nuclei). It seems to us, any theory is more beautiful if is more simple. In other kinds of composite models of quarks and leptons,[4] the origin of flavors and colors come from certain combinations of preons. But it has not considered the topological properties and space structures of combinations of preons. The origin of flavor and color still is an open problem in those models. In this paper, we would like to propose a possible new scenario of a composite model for quarks and leptons. The same idea may also be of interest to construct a composite model of Higgs particles or perhaps even intermediate bosons $W^{\pm}$ and Z°. Our model is very simple from its constituents. There are only two kinds of preons, named X and Y, which have four preons "valencies". It looks like a carbon atom with four chemical valencies. A quark or a lepton is a well-defined collection of preons that are attracted to each other such that the whole collection may be thought of as a single unit. The "attractive interaction" between two preons is called a preon bond. Clearly the preon bond must be something more specific than a hypercolor interaction between preons. In some sense, our methods of building-blocks of leptons and quarks apply the idea of the molecular strucure, more exactly said, the idea of the structure of the organic componds are applied. It is well known for chemists that there are many different kinds of hydrocarbon compounds which consist only of two kinds of atoms, *i.e.*, hydrogen and carbon. There also exists some sequences of the compounds which have similar properties from each other. From the idea of molecular compounds, we would like to explain the interaction which is responsible for binding the preons X and Y within a quark or a lepton as the van der Walls interaction of the new fundamental interaction and the $SU(3)$ color interaction of quarks as the residual forces of the van der Walls interaction. The electric charge of quarks and leptons not only from the charge of preons but also depends on topological properties of construction which might come from exciting the global structure of quarks and leptons.

We assume that:

1. We have two kinds of fundamental constituents, named X and Y preon. X and Y have four valencies, named preon's valency. The quarks and leptons, which are composite objects of these preons, are zero preon's valencies.

2. For simplicity, all of the X and Y's are fermions. From the statistics, we assume that the quarks and leptons consist from odd numbers of X, odd numbers of Y or odd numbers of X and Y, because the quarks and the leptons are fermions. In our model, to get three generations of quarks and leptons, the quarks and leptons consist of five preons. The preons put on the boundary of the compositeness.

3. The dimensions of the space occupied by preons are three, even the scale of space less than 1/TeV. Here we believe that the percent lower limit on compositeness scale is about up to TeV.[5] As we know, the space of three dimensions have subspace with $dim = 2$ and $dim = 1$. Here, from the view of structure, we do not consider the subspace with $dim = 0$.

4. Considering that a quark or lepton structure is very hard (to break quarks and leptons, we need more energy) and from the motivation of the properties of chemical compounds, we assume that the structure of quarks and leptons have the structure of a closed chain. It looks like the structure of the ring compound in benzene, *i.e.*, we do not consider the line chain structure which looks like the open-chain structure of C_nH_{2n+2} in organic compounds.

From the above assumptions, we can only get the following 24 different diagrams of the quark-lepton structure, which are just corresponding to three generations of leptons and quarks. The names of quarks and leptons are given for each structure diagram in Fig. 1. The fermionic presons X and Y are left-handed, so the left-handed composite staes can be constructed. The right handed composite states either made of different right preons or are point-like fundamental objects.

It is very interesting to note that a quark has three colors with different space structures or different bond forms, and the fundamental constituents are the same, but a lepton lacks color. There is no existence of exotic quarks and leptons, which are difficult to avoid in most composite models proposed so far.

From the quark-lepton structure diagram, as shown in Fig. 1, we can also see that

1. From topology, the structure of the leptons are different from that of quarks. The structure of leptons is a plannar which has $dim = 2$. But the structure of quarks is a three-dimensional structure. So, the topological structure of leptons and quarks is inequivalence because the dimensions of R^n is invariance topologically. There is not a homeomorphism f from R^2 to R^3. In Fact, R^2 occupied by leptons in our model is the (x, y) plane while R^3 occupied by quarks is the three dimensional (x, y, z) space. Suppose that there is a homeomorphism f from R^2 to R^3:

$$f: R^2 \rightarrow R^3$$

   If such a f existed then the dimension of R^2 and R^3 could not be topological invariants. To see that f cannot exist we only note that $R^2 - \{(0,0)\}$ and $R^3 - \{(0,0,0)\}$ are not homeomorphic. Take the two sets $R^2 - \{(0,0)\}$ and $R^3 - f\{(0,0)\}$ and consider the circle $x^2 + y^2 = r^2$. If we consider the limit $r \rightarrow 0$, then we obtain two distinct situations. In $R^3 - f\{(0,0)\}$ the circle may be shrunk right down to a point, so it can avoid the point $f\{0,0\}$. But in $R^2 - \{0,0\}$, it can not avoid the orgin $(0,0)$. It means that f cannot exist, because f should be continuous and invertible, if it exists.

   Perhaps this is why quarks have color but leptons lack color, and the three colors of quarks may come from three dimensional space. From the view of the "preon's molecular structure", the lepton and the quark are different in our model. In the lepton case, the preons with four valencies are bound to each other by double bonds, but in the quarks case, there exists a single bond in the structure. It may be the origin of quark color but the leptons lack of color.

2. In our mode, we can see in Fig. 1, that the $SU(2)$ isospin symmetry of neutrinos and charged leptons or up quark and down quarks for each generation corresponds with a permutation symmetry of X and Y preons. The three

different colors of the same quark only have different space structures and different bonds form but the components of preons are the same.

3. $SU(3)$ strong-interaction (QCD) may be considered as the van der Waalls force of a new preon's interaction with $dim = 3$. We also can see that in the lepton case with $dim = 2$, there are no tightly existing forces, because there are no single existing bonds. The connection of preons in the case of the lepton is totally closed by double bonds, *i.e.*, there is no residual force of the new preon's existing interaction. Of course, this is only an interesting idea which is not impossible. It is noted that there are three types of electrostatic interactions between uncharged molecules: dipole-dipole, dipole-induced dipole, and London forces. The three together are called van der Waals interactions. The average sum is always attractive and is the source of the forces bringing about the condensation of gases and the freezing of liquids. But, here the preson's interactions is unknown, so we cannot say any more about it. More detailed studies are needed.

4. Now, we discuss the charge of leptons and quarks, *i.e.*, can we give some new ideas on $U(1)$ electromagnetic interactions.

   We assume that

   Preon X has $\frac{-4}{15}$ charge
   and Preon Y has $\frac{-7}{15}$ charge.

   The charges formula with different diagrams in Fig. 1 are given by (to get corresponding three generations)

$$Q_g = nx + my + \frac{2}{3}D + \frac{(n-m)}{15}(g-1)(2g-3) \qquad (.2)$$

   where
   n is number of the X presons in each diagram,
   m is number of the Y presons in each diagram,
   D is the dimension of the diagram, so

$$D = \begin{cases} 2 & \text{for the leptons} \\ 3 & \text{for the quarks} \end{cases}$$

$$g = \begin{cases} 1 & \text{for the first generation} \\ 2 & \text{for the second generation} \\ 3 & \text{for the third generation} \end{cases}$$

From Eq. (2), it is easy to get the following Table 1

Particles	u	d	ν_e	e	c	s	ν_μ	μ	$t(?)$	b	ν_τ	τ
Charge	$\frac{2}{3}$	$-\frac{1}{3}$	0	-1	$\frac{2}{3}$	$-\frac{1}{3}$	0	-1	$\frac{2}{3}$	$-\frac{1}{3}$	0	-1

Table 1: The charge of the leptons and quarks

The possible meaning of Eq. (2) is that the charge of leptons and quarks not only come from the charge of preons, but also depend upon the topological properties of the composite for quarks and leptons.

5. Intermediate bosons $W^\pm$, Z° and Higgs bosons. Now if the intermediate bosons $W^\pm$, Z° and scalar Higgs particles are also probably composite objects, how can we describe them in our scenario? The simplest scenario is that we will introduce two scalar preons α and β, their quantum numbers are given in the following table:

scalar preons	color	electrical charge	spin	valencies
α	singlet	$+\frac{1}{2}$	0	0
β	singlet	$-\frac{1}{2}$	0	0

It is noted that the assignments of valencies of scalar preons are zero. We can see tht from the view of the valencies, α and β are neutral. So, α, β do not couple with preons X and Y, which have four valencies. But there is the interaction which is responsible for binnding the preons α and β within bosons as the van de Waals interaction of the new fundamental interaction so that the intermediate weak bosons are composed of two scalar preons only in the following usual way.

$$\begin{aligned} W^+_\mu &= \epsilon_{ij}\alpha^i D_\mu \alpha^j \\ W^-_\mu &= \epsilon_{ij}\beta^i D_\mu \beta^j \\ Z^\circ_\mu &= \epsilon_{ij}\alpha^i \overleftrightarrow{D_\mu}\, \beta^j \end{aligned}$$

We assume that these particles form a triplet under the global $SU(2)_w$. Since the right-handed quarks and leptons do not couple to $W^\pm$ and Z°, they cannot be composite states of the same preons as the left-handed ones. As we noted above that in our scheme right-handed states are either point-like fundamental objects or made of different preons. Thus, from the effective interaction theory, our scheme looks like the strongly coupled standard model proposed by M. Claudson, E. Farhi and R. L. Jaffee.[6] The most general $SU(2)_w$ invariant effective Lagrangian including all terms of dimension-4 or less is

$$L^\circ_{eff} = i\Psi_{La}\ \partial\!\!\!/ F^a_L - \frac{1}{4}\vec{W}^{\mu\nu}\cdot\vec{W}_{\mu\nu} + \frac{1}{2}M^2_w\,\vec{W}^\mu\vec{W}_\mu + \bar{g}\,\vec{W}^\mu\,\vec{j}_{L\mu}$$
$$- \frac{1}{2}g_3\,\vec{W}^{\mu\nu}\cdot(\vec{W}_\mu\times\vec{W}_\nu) + \frac{1}{4}g_4(\vec{W}^\mu\cdot\vec{W}_\mu)^2 + \frac{1}{4}g'_4(\vec{W}^\mu\cdot W^\nu)(\vec{W}_\mu\cdot\vec{W}_\nu)$$

where

$$\vec{W}_{\mu\nu} = \partial_\mu\vec{W}_\nu - \partial_\nu\vec{W}_\mu$$
$$\vec{j}^\mu_L = \frac{1}{2}\,\vec{F}^a_L\vec{\tau}\,\gamma^\mu F^a_L$$

and

$$\frac{\bar{g}^2}{2m_w} = \frac{4G_F}{\sqrt{2}}$$

which get from matching the usual four-fermion interactions. Following the way of Ref. 6, to reproduce the phenomenology of the fundamental $W^\pm$ and Z° of the $SU(2)\times U(1)$ standard model, we introdue spin-0 field

$$H = \frac{1}{\sqrt{2}}(\alpha\alpha^* + \beta\beta^*)$$

and identify the lowest mass state connected by this operator to the vacuum with the Higgs particle of the standard model. Thus, we expect that this scheme can account for all weak interaction phenomenology.

In conclusion, I would like to emphasize that the possibility of the new scenario of composite model for quarks and leptons, in which the topology and space properties of compositeness are considered, seems to be one of attractive and noble ones, although there are many problems which are still open.

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Figure Captions

Figure 1: The Structures of Quarks and Leptons.

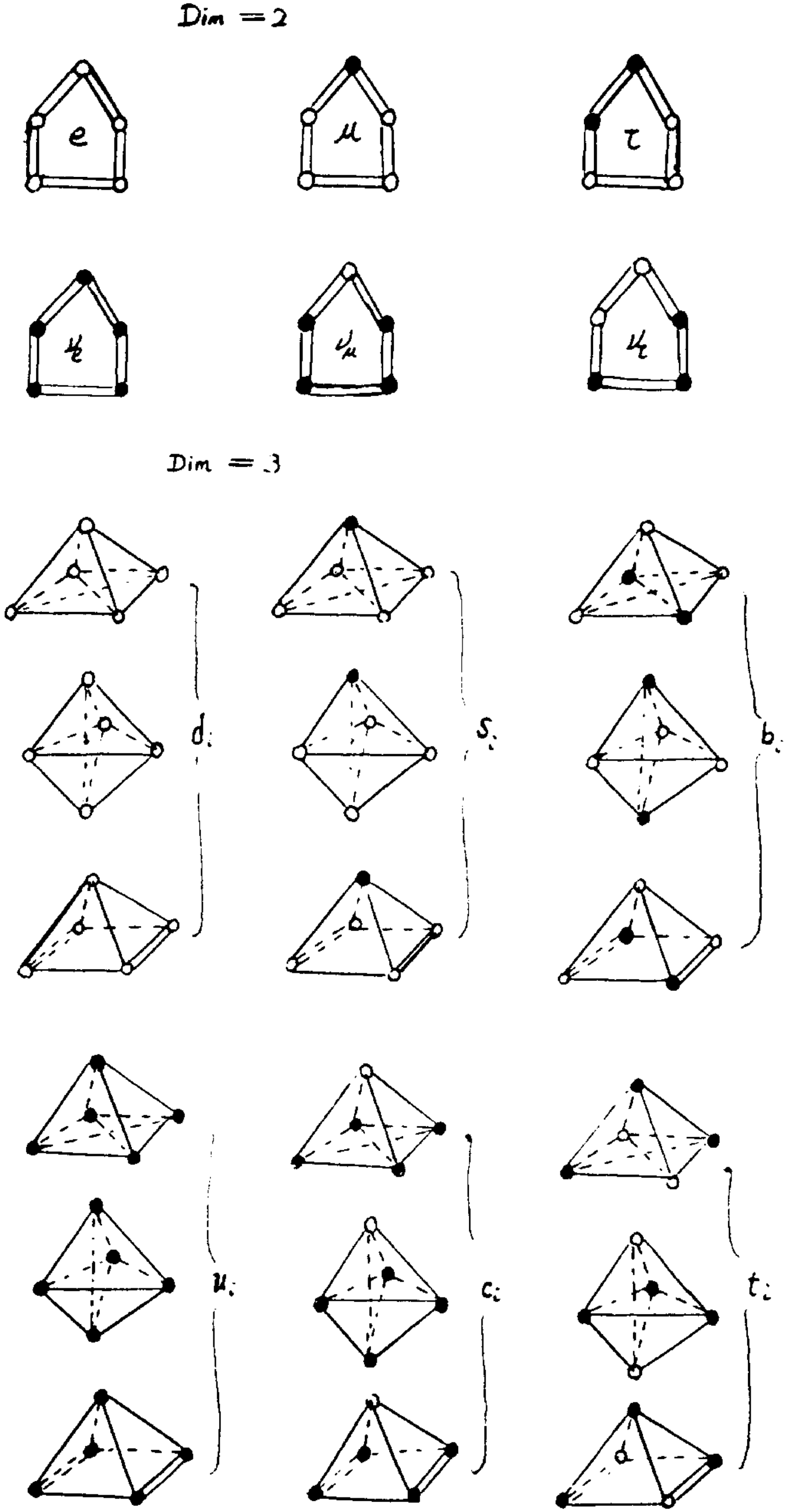
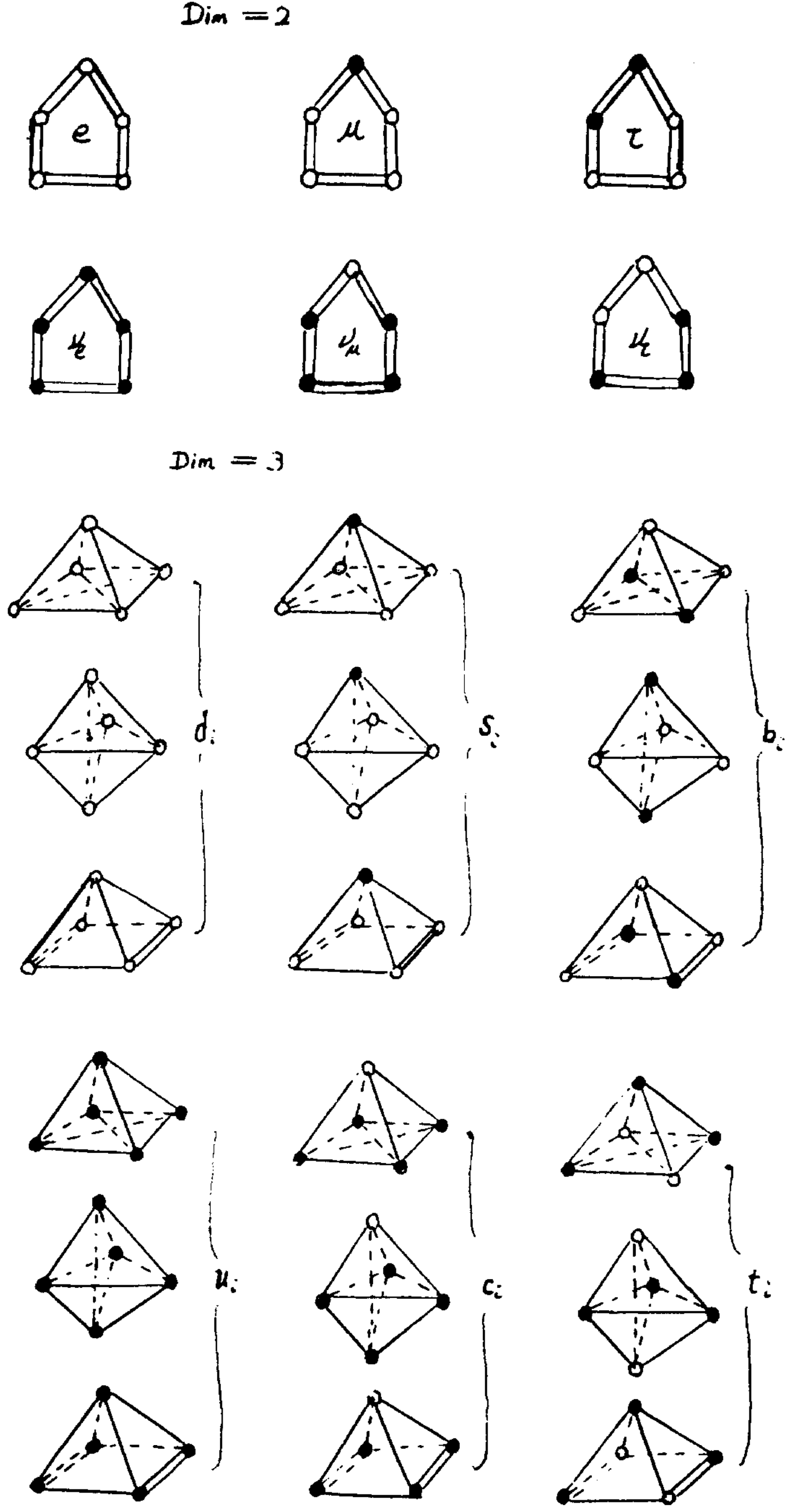


Fig. 1 ●— X preon ○— Y preon i — color index



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