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The Ultimate Division of Matter

Mário Everaldo de Souza

Departamento de Física – Universidade Federal de Sergipe 49100-000, São Cristóvão, SE, Brazil

mdesouza@ufs.br

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This work proposes that quarks are composite particles, composed of prequarks (called primons in this work) which are very light fermions. In this way we can explain the number of quarks and begin to understand why their masses cover a wide range of values. Moreover, we can understand what is behind the Kobaiashi-Maskawa matrix. Also, the proposal agrees with the experimental data of the recent RHIC data.

Keywords: prequarks; new SU(2).

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1. INTRODUCTION

It has been proposed by de Souza[1-8] that Nature has six fundamental forces. One of them, called superstrong force, acts between any two quarks and between quarks constituents. This work will deal only with this new force. Actually, quark composition is an old idea although it has been proposed on different grounds[9-12]. A major distinction is that in this work leptons are supposed to be elementary particles. This is actually consistent with the smallness of the electron mass which is already too small for a particle with a very small radius[13]. In order to distinguish the model proposed in this work from other models of the literature we name these prequarks with a different name. We call them primons, a word derived from the Latin word primus which means first.

Let us develop some preliminary ideas which will help us towards the understanding of the superstrong interaction. The work proposes that each quark is composed of two primons that interact by means of a new fundamental interaction called superstrong force.

In order to reproduce the spectrum of 6 quarks and their colors we need 4 primons (p_1, p_2, p_3, p_4) in 3 supercolor states (α,β,γ). Each color is formed by the two supercolors of two different primons that form a particular quark (Table 1). Therefore, the symmetry group associated with the supercolor field is SU(2). As to charge, one has charge (+5/6)e and any other one has charge (-1/6)e (Table 2).

Taking into account Tables 1 and 2 we construct the table of quark flavors (Table 3) which shows that the maximum number of quarks is six.

There should exist similar tables for the corresponding antiparticles of primons.

Table 1. Generation of colors from supercolors

	α	β	γ
α		blue	green
β	blue		red
γ	green	red	

Table 2. Electric charges of primons

Superflavor	charge
p_1	$+5/6$
p_2	$-1/6$
p_3	$-1/6$
p_4	$-1/6$

Table 3. Composition of quark flavors

	p_1	p_2	p_3	p_4
p_1		u	c	t
p_2	u		d	s
p_3	c	d		b
p_4	t	s	b	

2. SPIN AND ANISOTROPY OF SPACE INSIDE THE NUCLEON

What about spin? The spin of primons is a great puzzle in the same way as the spin of a quark is since as is well known only half of the spins of quarks contribute to the total spin of the nucleon, as has been found by experiments. Actually, the spin puzzle of the nucleon may be linked to the spin of primons. Since they are elementary fermions we expect them to be half spin fermions. And thus it is not an easy task to divise a way of making two half spin fermions to compose another half spin fermion. We begin solving the puzzle in the following way. When we make the addition of two different angular momenta we use the commutation relation

$$\left[\vec{S}_1, \vec{S}_2\right] = 0 \tag{1}$$

which means that their degrees of freedom are independent. But in the case of primons they are not independent since the two primons that compose a quark should always have their z projections equal to $(+1/4)\hbar + (+1/4)\hbar = +1/2\hbar$ or to $(-1/4)\hbar + (-1/4)\hbar = -1/2\hbar$ since the spin of each quak is $1/2\hbar$. This means that when a primon (of the same quark) changes its spin state to $(-1/4)\hbar$ the other primon has also to change its spin state to $(-1/4)\hbar$. Let us consider a u quark in the spin state $+(1/2)\hbar$. Thus we have that

$$\vec{S}_1^2 \varphi_1 = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2 \varphi_1 \tag{2}$$

$$\vec{S}_2^2 \varphi_2 = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2 \varphi_2 \tag{3}$$

$$S_{1z}\varphi_1 = +\frac{1}{4}\hbar\varphi_1 \tag{4}$$

$$S_{2z}\varphi_2 = +\frac{1}{4}\hbar\varphi_2 \tag{5}$$

where φ_1 and φ_2 are the spinors of p_1 and p_2. Moreover we have that

$$\vec{S}^2\varphi = \left(\vec{S}_1 + \vec{S}_2\right)^2 \varphi = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2\varphi . \tag{6}$$

$$\left(S_{1z} + S_{2z}\right)\varphi = +\frac{1}{2}\hbar\varphi \tag{7}$$

where φ is the u quark spinor. But we cannot say that $\varphi = \varphi_1\varphi_2$. This also means that for the two primons that compose a quark the raising and lowering spin operators $\hat{S}^+$ and $\hat{S}^-$ cannot be defined for each primon and therefore there is no way of finding $\hat{S}_x$ and $\hat{S}_y$, separately. We can only obtain that (for $+(1/2)\hbar$ p_1, for example)

$$\left(\hat{S}_x^2 + \hat{S}_y^2\right)\varphi_1 = \left(\hat{S}^2 - \hat{S}_z^2\right)\varphi_1 = \left(\frac{1}{2}\left(\frac{1}{2}+1\right) - \frac{1}{16}\right)\hbar^2\varphi_1 = \frac{11}{16}\hbar^2\varphi_1 . \tag{8}$$

And since *x* and *y* are equivalent directions we should have $\hat{S}_x^2\varphi_1 = \hat{S}_y^2\varphi_1 = 11/32$ We notice

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immediately that $\hat{S}_x^2\varphi_1 = \hat{S}_y^2\varphi_1 \neq \hat{S}_z^2\varphi_1$ which means that there is an intrinsic anisotropy of space caused by the fact that there is a preferred direction which is exactly the direction of the spin of the baryon. This may explain why the sum of the angular momenta of quarks (in the nucleon) only adds up to half of its spin. Let us recall again that all this is caused by confinement.

3. THE NEW HYPERCHARGE AND THE NEW SU(2)

In order to find the new hypercharge let us recall the relation between electric charge and baryon number in quarks. Quark charges 2/3 and –1/3 are symmetric about 1/6 and, since 2/3-(-1/3)=1=2(1/2), we have

$$Q = \frac{B}{2} \pm \frac{1}{2} \tag{9}$$

because 1/6=(1/2)(1/3)=B/2. Equation (9) is in line with the formula

$$Q = I_3 + \frac{1}{2}\left(B + S + C + B^* + T\right) \tag{10}$$

where I_3 is the isospin component of the isospin *I*, *B*=1/3 is the baryon number and *S*,*C*,*B**,*T* denote the quark numbers for the quarks s,c,b and t, respectively. *C* and *T* are equal to 1 and *S* and *B** are equal to –1. The above formula (Eq. 10) can also be written as

$$Q = I_3 + \frac{Y}{2} \tag{11}$$

which is the Gell-Mann--Nishijima relation where Y is the strong hypercharge. Since each primon has B=1/6 Eq. 9 is not valid. Instead of it we should have

$$Q = 2B \pm \frac{1}{2} \tag{12}$$

because electric charges are symmetric about 1/3 since 1/3=2(1/6)=2B. This implies that for a system of primons (a quark)

$$Q = 2B + \frac{1}{2}(P_1 + P_2 + P_3 + P_4) \tag{13}$$

where B is the total baryon number, and $P_1 = 1$, $P_2 = P_3 = P_4 = -1$. From this we note that we may divide primons into two distinct categories and we should search for a new quantum number to caracterize such distinction. Therefore, we have

$$\frac{2}{3} = 2\times\left(\frac{1}{6}+\frac{1}{6}\right)+\frac{1}{2}(1+1) \qquad \text{for u,c,t} \tag{14}$$

and

$$-\frac{1}{3} = 2\times\left(\frac{1}{6}+\frac{1}{6}\right)+\frac{1}{2}(-1-1) \qquad \text{for d,s,b} \tag{15}$$

Because quarks u and d have isospins equal to 1/2 and -1/2, respectively, we are forced to make $I_3 = \pm 1/4$ for primons p_1 and p_2. We will see in detail below how I_3 can be assigned to them. And we will be able then to find that the other primons also have $I_3 = \pm 1/4$.

Let us try to write a simple expression for the charge of primons like the one that is used for the nucleon. Following the footsteps of the strong hypercharge we can try to make

$$Q = I_3 + \frac{Y}{2} \tag{16}$$

where Y is the new hypercharge (called superhypercharge) and is given by

$$Y = B + \Sigma \tag{17}$$

where Σ is a new quantum number (called supersigma) to be found. Thus the formula becomes

$$Q = I_3 + \frac{1}{2}\left(B + \Sigma_3\right) \tag{18}$$

which is quite similar to the Gell-Mann--Nishijima formula used for quarks $Q = I_3 + \frac{1}{2}(B+S)$.

From now on instead of dealing with the new hypercharge $Y = B + \Sigma$ we will deal directly with Σ. As was discussed above we should try $\Sigma_3 = +1$ for p_1 and $\Sigma_3 = -1$ for p_2, p_3, p_4. Therefore,

$$\frac{5}{6} = \frac{1}{4} + \frac{1}{2}\left(\frac{1}{6}+1\right) \qquad \text{for } p_1 \tag{19}$$

and

$$-\frac{1}{6}=\frac{1}{4}+\frac{1}{2}\left(\frac{1}{6}-1\right) \qquad \text{for } p_2, p_3, p_4 \tag{20}$$

As we will see shortly p_2, p_3, p_4 can also have $I_3=-1/4$. In this case we have

$$-\frac{1}{6}=-\frac{1}{4}+\frac{1}{2}\left(\frac{1}{6}+0\right) \qquad \text{for } p_2, p_3, p_4 \tag{21}$$

This means thus that Σ_3 can assume the values –1,0, and +1 and, thus, they can be considered as the projections of $\Sigma=1$. Of course $\Sigma_3=0$ can also be the projection of $\Sigma=0$. Putting all together in a table one has

	I_3	Σ_3
p_1	$+\frac{1}{4}$	$+1$
p_j $(j=2,3,4)$	$+\frac{1}{4}$	-1
	$-\frac{1}{4}$	0

Let us now find the values of Σ for quarks. The results are quite impressive because they are directly linked to the Kobayashi-Maskawa matrix and to the quark doublets

$$\begin{pmatrix} u \\ d \end{pmatrix}, \begin{pmatrix} c \\ s \end{pmatrix}, \begin{pmatrix} t \\ b \end{pmatrix}.$$

As was seen above p_1 can only have $I_3=1/4$, and p_2, p_3, p_4 can have $I_3=\pm 1/4$. In the case of the u quark p_1 has $I_3=1/4$ and p_2 has $I_3=1/4$ because $I_3=1/2$ for *u*, and then its value of Σ_3 is $+1+(-1)=0$. For the *d* quark p_2 has $I_3=-1/4$ and p_3 has $I_3=-1/4$ since I_3 for *d* is –1/2, and its total Σ_3 is thus $0+0=0$. In the case of *c* and *t* quarks, since p_1 has $I_3=1/4$, p_2 and p_3 should have $I_3=-1/4$ because the I_3 of both quarks is equal to 0. In both cases the total Σ_3 is equal to +1+0=+1. Also s and b have opposite I_3´s and Σ_3 equal to either $-1+0=-1$ or to $0+(-1)=-1$. Hence a system of two primons (a quark) has the four possible states $\left|\Sigma,\Sigma_3\right\rangle$:

$\left\|1,+1\right\rangle$ for c,t $\left\|1,0\right\rangle$ for d $\left\|1,-1\right\rangle$ for s,b	$\left\|0,0\right\rangle$ for u

The choice $\left|1,0\right\rangle$ for d, $\left|0,0\right\rangle$ for u was made considering that the u quark is the end product of the decays of quarks which means that it should be singled out. Making a table with the results we obtain

	I_3	Σ_3
c,t	0	$+1$
u	$+1/2$	0
d	$-1/2$	0
s,b	0	-1

and the quark doublets

$$\begin{pmatrix} |0,0\rangle \\ |1,0\rangle \end{pmatrix}, \begin{pmatrix} |1,+1\rangle \\ |1,-1\rangle \end{pmatrix},. \begin{pmatrix} |1,+1\rangle \\ |1,-1\rangle \end{pmatrix}$$

which should be compared to

$$\begin{pmatrix} u \\ d \end{pmatrix}, \begin{pmatrix} c \\ s \end{pmatrix}, \begin{pmatrix} t \\ b \end{pmatrix}.$$

Putting the values of I_3 and Σ_3 in a diagram we obtain Fig. 1 below

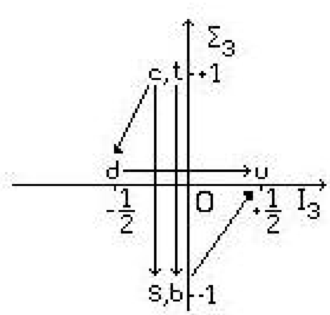

Figure 1. Diagram that shows how the decays of quarks are related to a new hypercharge and to isospin. It is directly related to the Kobayashi-Maskawa matrix.

Comparing Figure 1 with the Kobayashi-Maskawa matrix we note that the elements of the matrix $|U_{cs}|$ and $|U_{tb}|$ (which are the largest ones are almost equal to 1) satisfy the selection rule $\Delta\Sigma_3 = -2$, and the other large element $|U_{ud}|$ (which is also close to 1) satisfies the selection rule $\Delta\Sigma = -1$, $\Delta\Sigma_3 = \Sigma_3 = 0$. The other large elements $|U_{cd}|$(=0.24) and $|U_{us}|$ (=0.23) obey, respectively, the selection rules $\Delta\Sigma_3 = -1$, $\Delta\Sigma = 0$, and $\Delta\Sigma_3 = +1$, $\Delta\Sigma = -1$. The almost null elements $|U_{ts}|$ and $|U_{cb}|$ can also be understood according to the above scheme if we also take into account the three quark doublets. According to the scheme flavor changing neutral currents are forbidden because in such a case $\Delta\Sigma_3 = 0$. Taking a glance at the above diagram we can understand why $|U_{cs}| \approx |U_{tb}|$ and $|U_{td}| \approx |U_{ub}|$. Another very important conclusion is that the b and t quarks are heavier versions of the s and c quarks, respectively.

If we represent the values of Σ_3 by arrows as we do with spin or isospin we have

$$c = p_1 \uparrow p_3 \uparrow; \; t = p_1 \uparrow p_4 \uparrow; \; |1,+1\rangle$$
$$d = \frac{1}{\sqrt{2}}\left(p_2 \uparrow p_3 \downarrow + p_2 \downarrow p_3 \uparrow\right); \; |1,0\rangle$$
$$s = p_2 \downarrow p_4 \downarrow; \; b = p_3 \downarrow p_4 \downarrow; \; |1,-1\rangle$$

and

$$u = \frac{1}{\sqrt{2}}\left(p_1 \uparrow p_2 \downarrow - p_1 \downarrow p_2 \uparrow\right); \; |0,0\rangle$$

and thus there is a SU(2) related to Σ and consequently a vectorial supercurrent

$$j_\mu^\Sigma = \overline{\psi}\gamma_\mu \Sigma \psi \,. \tag{22}$$

We clearly notice that since both t and c have p_1 the mass difference between them is directly linked to how p_3 and p_4 interact with p_1 because these two quarks have the same Σ and the same Σ_3. The same reasoning happens between quarks s and b which have p_4 in common. As a given primon takes part in the composition of heavy and light quarks primons probably have the same mass which should be a light mass. More on this we will see in the next section.

This new SU(2) is in complete agreement with weak isospin and, thus, the Weinberg-Salam model (applied to quarks) does not need any deep modification since the symmety continues to be the same.

Concluding this section we say that what is behind the Kobaiashi-Maskawa matrix is the composition of quarks.

4. THE MASSES OF PRIMONS

The magnetic moments of primons should be given by $\mu_1 = \frac{5}{6}\frac{e}{2m_1}$ for p_1 and $\mu_2 = -\frac{1}{6}\frac{e}{2m_2}$ for p_2, p_3, p_4 and hence $\mu_1 = -\frac{5m_2}{m_1}\mu_2$; $\mu_3 = \frac{m_2}{m_3}\mu_2$.

Considering that the spin content of quarks should be the same we have

$$\frac{\mu_u}{\mu_d} = \frac{\mu_1 + \mu_2}{\mu_2 + \mu_3} \tag{23}$$

and since $\mu_u / \mu_d = -2$ and using the above relations we obtain

$$-2 = -\frac{5m_2}{m_1}\left(\frac{1 - \dfrac{m_1}{5m_2}}{1 + \dfrac{m_2}{m_3}}\right). \tag{24}$$

Making $m_3 = fm_2$ and solving for the ratio m_1 / m_2 we arrive at

$$\frac{m_1}{m_2} = \frac{5}{3 + \frac{2}{f}} \tag{25}$$

and as the mass of $u(p_1 p_2)$ and $d(p_2 p_3)$ are approximately equal it is reasonable to suppose that $m_3 \approx m_1$ and thus

$$f \approx \frac{5}{3 + \frac{2}{f}} \tag{26}$$

which yields $f \approx 1$ and hence $m_3 \approx m_2$. Then it is reasonable to assume that primons have approximately the same mass.

Primons may be very difficult to be found because they should be very light fermions and therefore, deep inelastic scattering only sees their combinations, that is, quarks which are much heavier particles.

5. PRIMON: THE ULTIMATE UNIT OF HADRONS

It is easy to see that primons cannot be composed particles: atoms are composed of nucleons and electrons, nucleons are composed of 3 quarks and each quark is composed of 2 primons, and thus, a primon cannot be divided because then there would be a repetition in the number of units. That is, if a primon were a composed particle it would be composed of at least 2 other particles but 2 was already used above. This means that the composition of the units of matter is not ad infinitum. Thus primons are the ultimate units of hadrons and are as elementary as the electron. It is not an easy task to see a primon because they should be very light fermions that form a very heavy fermion which is a baryon. For this purpose we should compare the results of high, intermediate and low energy inelastic electron scattering.

6. THE CONFINED WORLD IS A STRANGE FRACTIONAL WORLD

Taking into account what has been developed in the previous sections we arrive at the conclusion that the confined world, that is, the world inside baryons is a quite strange world where charge is fractional at the level of quarks and primons and spin is fractional at the level of primons. The same holds for the isospins of primons which are $\pm 1/4$.

As we saw above primons only exist in pairs, forming quarks, and thus, a baryon is actually a very ordered set of six primons, arranged into three quarks. Therefore, free primons do not exist, and hence all this casts doubt on the existence of quark matter, that is, primonic matter. This is quite in line with the Universe having an initial baryonic mass constituted of squeezed nucleons. This is exactly what the four groups of RHIC have recently found at Brookhaven [14].

As we see above the confined world is characterized by some fractional quantities. And since this fractional character always existed this matter was never free and is, therefore, a non-created matter.

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