Quark Mass, Quark Compositeness, and Solution to the Proton Spin Puzzle

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This work shows that the proton spin puzzle and the origin of quark mass are natural consequences of the compositeness of quarks which also generates a continuous symmetry breaking. And is also quark compositeness what is behind the Kobaiashi-Maskawa matrix. Moreover, the paper shows that prequarks (primons) have already been found by the first EMC experiment in the 1980s.

Keywords: proton spin puzzle, origin of mass, prequarks; new SU(2).

1. INTRODUCTION

It has been proposed by de Souza[1-10] 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 compositeness is an old idea although it had been proposed on different grounds[11-14]. 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[15]. 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 1.1). 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 2.1).

Taking into account Tables 1.1 and 2.1 we construct the table of quark flavors (Table 3.1) which shows that the maximum number of quarks is six.

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

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

Table 1.1. Generation of colors from supercolors

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

Table 2.1. Electric charges of primons

	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	

Table 3.1. Composition of quark flavors

2. 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

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

because 1/6=(1/2)(1/3)=B/2. Equation (01) is in line with the formula

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

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. 02) can also be written as

$$Q = I_3 + \frac{Y}{2} \tag{3}$$

which is the Gell-Mann--Nishijima relation where Y is the strong hypercharge. Since each primon has B=1/6 Eq. 01 is not valid. Instead of it we should have

$$Q = 2B \pm \frac{1}{2} \tag{4}$$

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)

$$Q = 2B + \frac{1}{2}(P_1 + P_2 + P_3 + P_4) \tag{5}$$

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

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

and

$$-\frac{1}{3} = 2\times\left(\frac{1}{6} + \frac{1}{6}\right) + \frac{1}{2}(-1-1) \qquad \text{for d,s,b} \tag{7}$$

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

$$Q = I_3 + \frac{Y}{2} \tag{8}$$

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

$$Y = B + \Sigma \tag{9}$$

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

$$Q = I_3 + \frac{1}{2}(B + \Sigma_3) \tag{10}$$

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,

$$\frac{5}{6} = \frac{1}{4} + \frac{1}{2}\left(\frac{1}{6} + 1\right) \qquad \text{for } p_1 \tag{11}$$

and

$$-\frac{1}{6} = \frac{1}{4} + \frac{1}{2}\left(\frac{1}{6} - 1\right) \qquad \text{for } p_2, p_3, p_4 \tag{12}$$

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

$$-\frac{1}{6} = -\frac{1}{4} + \frac{1}{2}\left(\frac{1}{6} + 0\right) \qquad \text{for } p_2, p_3, p_4 \tag{13}$$

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 $|\Sigma, \Sigma_3\rangle$:

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

The choice $|1,0\rangle$ for d, $|0,0\rangle$ 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

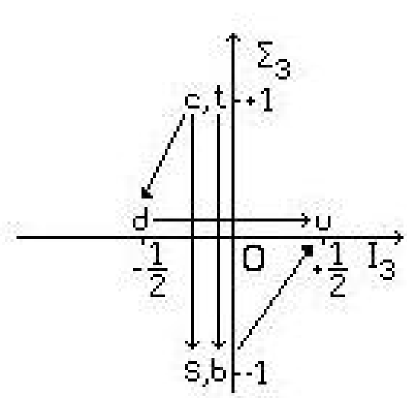

Figure 1.2. Diagram that shows how the decays of quarks are related to a new hypercharge and to isospin. It is directly related to the Kobayashi-Maskawa matrix.

Comparing Figure 1 with the Kobayashi-Maskawa matrix we note that the matrix elements $|U_{cs}|$ and $|U_{tb}|$ (which are the largest ones and 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 when $\Delta\Sigma_3 = 0$. Another very important conclusion is that b and t quarks are heavier versions of the s and c quarks, respectively, and that is why $|U_{cs}| \approx |U_{tb}|$.

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

$$j_\mu^\Sigma = \overline{\psi}\gamma_\mu \Sigma \psi . \tag{14}$$

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 note that what is behind the Kobaiashi-Maskawa matrix is the compositeness of quarks.

3. 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

$$\frac{\mu_u}{\mu_d} = \frac{\mu_1 + \mu_2}{\mu_2 + \mu_3} \tag{15}$$

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

$$-2 = -\frac{5m_2}{m_1}\left(\frac{1-\frac{m_1}{5m_2}}{1+\frac{m_2}{m_3}}\right). \tag{16}$$

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

$$\frac{m_1}{m_2} = \frac{5}{3+\frac{2}{f}} \tag{17}$$

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

$$f \approx \frac{5}{3+\frac{2}{f}} \tag{18}$$

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.

4. SPIN AND SPACE ANISOTROPY IN 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 is directly 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

$$\left[\vec{S}_1, \vec{S}_2\right] = 0 \tag{19}$$

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 $(-1/4)\hbar$. Therefore, the spin of primons are not independent. Let us consider a u quark in the spin state $+(1/2)\hbar$. Thus we have that

$$\vec{S}_1^2 \varphi_1 = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2 \varphi_1 \tag{20}$$

$$\vec{S}_2^2 \varphi_2 = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2 \varphi_2 \tag{21}$$

$$S_{1z} \varphi_1 = +\frac{1}{4}\hbar \varphi_1 \tag{22}$$

$$S_{2z}\varphi_2 = +\frac{1}{4}\hbar\varphi_2 \tag{23}$$

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

$$\vec{S}^2\varphi = \left(\vec{S}_1 + \vec{S}_2\right)^2\varphi = \frac{1}{2}\left(\frac{1}{2}+1\right)\hbar^2\varphi. \tag{24}$$

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)

$$\left(\hat{S}_x^2 + \hat{S}_y^2\right)\varphi_1 = \left(\hat{S}^2 - \hat{S}_z^2\right)\varphi_1 = \left(\frac{1}{2}\left(\frac{1}{2}+1\right) - \frac{1}{16}\right)\hbar^2\varphi_1 = \frac{11}{16}\hbar^2\varphi_1. \tag{25}$$

And since x and y are equivalent directions we should have $\hat{S}_x^2\varphi_1 = \hat{S}_y^2\varphi_1 = \frac{11}{32}\varphi_1$ and $\hat{S}_z^2\varphi_1 = \frac{2}{32}\varphi_1$. Thus $\hat{S}_x^2\varphi_1 = \hat{S}_y^2\varphi_1 \neq \hat{S}_z^2\varphi_1$ 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 nucleon. We can interpret this as a contiuous symmetry breaking. It is a consequence of confinement and of having six half spin fermions forming three half spin fermions and these forming a nucleon which is also a half spin fermion.

5. SIZES AND MASSES OF QUARKS

Having in mind what was developed in references 1 and 2 it is reasonable, therefore, to consider that the two primons that form a quark (inside a baryon) are bound by the combination of the strong and superstrong interactions. Therefore, they should generate an effective potential well. Each well has to have just one bound state which is the mass of each quark.
The heavier a quark is the deeper should be the effective well between its two primons. Also, the well should be narrower because the heavier a quarks is the more it should be bound. For a given quantum number, n, the energy of a well increases as it narrows. The effective potential of the top quark is extremely deep since it is much more massive than the other quarks. We are able, then, to understand the decays of quarks. The lowest level is, of course, the ground state of the u quark. The ground state of d is slightly above that of u and the ground state of s is above the ground state of the d. This should also happen for the other heavier quarks. These potentials and bound states are in line with the observed decay chain $b \rightarrow c \rightarrow s \rightarrow u$ and with the decays $d \rightarrow ue\bar{\nu}_e$ and $b \rightarrow s\gamma$.

Let us now see what is behind quark masses. Several researchers have tried to relate their masses to something more fundamental. In order to do this let us consider that the masses are levels of effective wells and let us approximate each well by an infinite potential well, that is, the mass of each quark (in units of energy), should be given by

$$E_q = \frac{\hbar^2\pi^2}{8ma^2} \tag{26}$$

where *m* is primon´s mass and *a* is of the order of the average size of each quark. Since each mass corresponds to a single level in each well, and considering that primons have approximately the same mass, we obtain that each quark mass should be related to the average distance between each pair of primons, that is, to the width of each well. Therefore, we should have the approximate relations:

$$0.3 = \frac{C}{(R_u)^2}; 0.5 = \frac{C}{(R_s)^2}; 1.5 = \frac{C}{(R_c)^2}; 5 = \frac{C}{(R_b)^2}; 150 = \frac{C}{(R_t)^2} \tag{27}$$

where C is a constant and R_u , R_s , R_c , R_b , R_t are the widths of the wells. These relations can also be obtained, using Heisenberg´s uncertainty principle.

As is discussed in section 2 of reference 1, $R_u \approx 0.5F$. We may assume that $R_u \approx R_d$. We arrive at the very important relations about quark sizes:

$$(R_s)^2 = \frac{3}{5}(R_u)^2 = 0.6(R_u)^2 \approx 0.15F^2 \tag{28}$$

$$(R_c)^2 = \frac{5}{15}(R_s)^2 = \frac{5}{15}\frac{3}{5}(R_u)^2 = 0.2(R_u)^2 \approx 0.05F^2 \tag{29}$$

$$(R_b)^2 = \frac{15}{50}(R_c)^2 = \frac{15}{50}\frac{5}{15}\frac{3}{5}(R_u)^2 = 006(R_u)^2 \approx 0.015F^2 \tag{30}$$

$$(R_t)^2 = \frac{5}{150}(R_c)^2 = \frac{50}{1500}\frac{15}{50}\frac{5}{15}\frac{3}{5}(R_u)^2 = 0002(R_u)^2 \approx 0.0005F^2 \tag{31}$$

It is quite interesting that there are some very fascinating relations. A very important one is:

$$\frac{m_d}{m_u} = \frac{(R_u)^2}{(R_d)^2} = 1 = 3^0 \tag{32}$$

$$\frac{m_c}{m_s} = \frac{(R_s)^2}{(R_c)^2} = 3 = 3^1 \tag{33}$$

$$\frac{m_t}{m_b} = \frac{(R_b)^2}{(R_t)^2} = 30 \approx 3^3 \tag{34}$$

and, thus, there is a factor of 10 between the last two relations. Other quite important relations are:

$$\frac{m_b}{m_c} = \frac{(R_s)^2}{(R_b)^2} = 10 \approx 3^2 \tag{35}$$

$$\frac{m_t}{m_c} = \frac{(R_c)^2}{(R_t)^2} = 100 \approx 3^4 \tag{36}$$

which has the same factor of 10. Therefore, the heavier a quark is the smaller it is. The approximation $100 \approx 3^4$ is completely justified because we approximated the finite well by an infinite well and also made the top quark mass approximately equal to 150GeV.

The above results agree quite well with the work of Povh and Hüfner[16] that have found $< r^2 >_{u,d} = 0.36\, fm^2$ and $< r^2 >_s = 0.16\ fm^2$ as effective radii of the constituent quarks. Also Povh[17] reports the following hadronic radii: $< r_h^2 >= 0.72\, fm^2$ for proton,

$< r_h^2 >= 0.62\, fm^2$ for Σ^-, $< r_h^2 >= 0.54\, fm^2$ for Ξ^-, $< r_h^2 >= 0.43\, fm^2$ for π^-, and $< r_h^2 >= 0.37\, fm^2$ for K^-. These radii clearly indicate that the *s* quark is smaller than the *u* quark.

In order to have very light primons we can consider that every pair of primons of a quark are bound by means of a very strong spring. Since every potential well has just one level we have the mass of each quark equal to

$$m_q c^2 \approx \frac{\hbar\omega}{2} = \frac{\hbar}{2}\sqrt{\frac{k}{\mu_p}} \tag{37}$$

in which μ_p is the reduced mass of the pair of primons and *k* is the effective constant of the spring between them. It is worth mentioning that a quite similar idea is used for explaining quark confinement and based on it a term *Kr* is introduced in the effective potential. For the *u* quark, for example, we have $m_u c^2 \approx 0.3 GeV$. On the other hand if we consider a harmonic potential we have

$$m_q c^2 \approx \frac{1}{2} k_u R_q^2 \tag{38}$$

where R_q is the size of the quark. For *u* we obtain $k_u \approx 10^{20}\, J/m^2 \approx 2Gev/\, fm^2$. Using this figure above we obtain $\mu_p \approx 10^{-28} kg$ which is about the proton mass. Therefore, in order to have light primons the effective well has to have a larger dependence with the distance between the two primons. Considering that the potential is symmetrical about the equilibrium position we may try to use the potential

$$V(x) = a_u x^4 \tag{39}$$

whose energy levels are given by

$$E_n = \left[\sqrt{\frac{\pi}{2\mu}} \nu\hbar a_u^{1/\nu} \frac{\Gamma\left(\frac{3}{2}+\frac{1}{\nu}\right)}{\Gamma\left(\frac{1}{\nu}\right)} \right]^{2\nu/(2+\nu)} (n+\frac{1}{2})^{2\nu/(2+\nu)}. \tag{40}$$

For $\nu = 4$ and $n = 0$ we have

$$E_0 = \left[\sqrt{\frac{\pi}{2\mu}} \nu\hbar a_u^{1/4} \frac{\Gamma\left(\frac{3}{2}+\frac{1}{4}\right)}{\Gamma\left(\frac{1}{4}\right)} \right]^{4/3} (0+\frac{1}{2})^{4/3}. \tag{41}$$

from which we obtain (making $E_0 = m_q c^2$)

$$\mu_p \sim 0.25\hbar^2 \sqrt{\frac{a_u}{\left(m_q c^2\right)^3}} \qquad 2)$$

which can be very light depending on the value of a_u. The above figure should be taken with caution because it is a result of nonrelativistic quantum mechanics.

Thus, if primons interact via a very strong potential such as $V(x) = a_u x^4$ they can be very light fermions. We can then propose a more general effective potential of the form

$V(x)=\frac{1}{4}a_u x^4-\frac{1}{2}k_u x^2$ where the last term is chose negative. Generalizing the coordinate *x* we can consider the "potential energy"

$$V_0(\phi)=\frac{1}{4}\lambda^2\phi^4-\frac{1}{2}\mu\phi^2 \tag{43}$$

where ϕ is a field related to the presence of the two primons (or other primons of the same baryon) and is connected to the scalar interaction between them, and μ and λ are real constants. Hence we can propose the Lagrangian

$$L_0=\frac{1}{2}(\partial_\nu\phi)(\partial^\nu\phi)+\frac{1}{2}\mu^2\phi^2-\frac{1}{4}\lambda^2\phi^4 \tag{44}$$

between the two primons of a quark. Since a quark only exists by means of the combination of the two primons we may consider that its initial mass is very small. The above Lagrangian is symmetric in ϕ but let us recall that primons can interact by other means, electromagnetically, for example. Therefore, we can make the transformation $\phi\rightarrow\phi+\eta_e$ where η_e is a deviation caused by the electromagnetic field.and vacuum. The new potential energy up to second power in η_e is

$$V(\phi,\eta_e)=V_0-\mu^2\phi\eta_e-\frac{1}{2}\mu^2\eta_e^2+\lambda^2\phi^3\eta_e+\frac{3}{2}\lambda^2\phi^2\eta_e^2. \tag{45}$$

$V(\phi,\eta_e)$ has a minimum at

$$\eta_e(\phi)=\frac{-\mu^2\phi+\lambda^2\phi^3}{\mu^2-3\lambda^2\phi^2}. \tag{46}$$

As η_e is small let us make $\mu^2\phi-\lambda^2\phi^3=\delta$ (a small quantity). Then we can make $\phi\approx\pm\frac{\mu}{\lambda}+\varepsilon$ and obtain $\varepsilon\approx-\frac{\delta}{2\mu^2}$ and thus

$$\phi\approx\pm\frac{\mu}{\lambda}-\frac{\delta}{2\mu^2} \tag{47}$$

and the symmetry has disappeared. But it is not spontaneously broken, it is broken by the perturbation ε which can occur all the time. Substituting the above value of ϕ into Eq 45 we obtain

$$U(\eta)=V(\phi,\eta)-V_0\approx\mu^2\eta^2 \tag{48}$$

and the approximate Lagrangian is

$$L_0=\frac{1}{2}(\partial_\nu\eta)(\partial^\nu\eta)-\mu^2\eta^2 \tag{44}$$

which is a Klein-Gordon Lagrangian with mass

$$m=\sqrt{2}\mu\hbar/c \tag{45}$$

which may be an effective mass. This is in complete agreement with the ideas above discussed on primons for as we saw the two primons of a quark have to interact by means of a scalar field because the z components of their spins are only $(1/4)\hbar$ each. Taking a look at Table 1.5 we observe that we need three scalar bosons, η^+, η^- and η^0. These are similar to the Higgs bosons. The first and second particles are exchanged between the primons of the quarks $p_1p_2(u)$, $p_1p_3(c)$, and $p_1p_4(t)$, and the neutral boson is exchanged between the primons of the quarks $p_2p_3(d)$, $p_2p_4(s)$ and $p_3p_4(b)$. Therefore, three bosons produce the masses of quarks. This is also in line with the recent observations about the beginning of the Universe which have shown that the Universe expanded from an initial mass[25].

It is quite interesting that we should have a triplet of scalar bosons. And we notice immediately a very important trend: The charged bosons produce masses larger than those produced by the neutral boson, considering the quark generations

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

Therefore, the origin of mass in quarks is also linked to the origin of charge. This is summarized below in Table 1.5.

Quark	Mass (GeV)	Charge	Mass Generator
$u(p_1 p_2)$	0.3	$+2/3$	$\eta+, \eta^-$
$c(p_1 p_3)$	1.5	$+2/3$	$\eta+, \eta^-$
$t(p_1 p_4)$	170	$+2/3$	$\eta+, \eta^-$
$d(p_2 p_3)$	0.3	$-1/3$	η^0
$s(p_2 p_4)$	0.5	$-1/3$	η^0
$b(p_3 p_4)$	4.5	$-1/3$	η^0

Table 1.5. The masses of quarks and their generators. In general the quarks generated by charged bosons have larger masses and larger charges than those generated by the beutral boson.

6. THE COUPLING CONSTANTS OF MASS

As was shown in section 4 there is an intrinsic spin anisotropy in the quarks of the nucleon. If the spins of primons were isotropic we would have found $< S_z^2 >= \frac{1}{4}\hbar^2$ instead of $\frac{2}{32}\hbar^2$ and thus there is a lack of $\left(\frac{1}{4} - \frac{2}{32}\right)\hbar^2 = \frac{3}{16}\hbar^2$ for each primon. For each quark we should have then a $\Delta S_z^2 = 2(3/16)\hbar^2$. We can consider that this as a continuous symmetry breaking that contributes to the formation of each quark mass. Taking into account the units of energy and angular momentum we can propose that the mass of each quark should be proportional to $\sqrt{\Delta S_z^2} = \hbar\sqrt{3/8}$, that is, $mc^2 \propto \hbar\sqrt{\frac{3}{8}}\frac{c}{l}$ where l is of the order of the quark size. This equation was chosen linear in $\hbar$ because in general energies related to spin are linear in $\hbar$ while energies related to angular momentum are in general proportional to $\hbar^2$ or to $\hbar$. And as is seen above, in Table 1.5, the masses of quarks should also have a dependence on the charges of their primons. Thus the mass of a quark (in the nucleon) should be given by

$$mc^2 = K\left[\left(\sqrt{\frac{3}{8}}\hbar\frac{c}{l}\right)\left(K_C\frac{|q_1q_2|}{l}\right)\right]^{1/2} \tag{46}$$

where K_C is Coulomb´s constant, q_1 and q_2 are the primon charges, *l* is of the order of the quark size and *K* is a dimensionless constant.

Let us make use of the above formula to calculate *K* for the *u* quark. In this case we have the following: $mc^2 = 0.3GeV$, $l \approx 0.6F$, $|q_1q_2| = \left(5/36\right)C^2$. We obtain $K_u \approx 25$. Doing the same for the other quarks we obtain the results shown below.

Quark	*K*	mc^2 (GeV)
u	25	0.3
c	46	1.5
t	1650	170
d	56	0.3
s	61	0.5
b	168	4.5

Table 1.6. The mass coupling constants of quarks. *K* is dimensionless

It is important to note that *u*, *c*, *d* and *s* have mass coupling constants of the same order of magnitude and thus, *t* and *b* are separate.This is in line with what we found in section 2: *t* and *b* are heavier versions of *c* and *s*.

7. SOLUTION TO THE PROTON SPIN PUZZLE

The latest results of CERN, DESY and SLAC have shown that quarks contribute to only 30% of proton´s spin[18-21]. The experiments have also revealed that gluons and the quark sea do not contribute much to the proton spin. I will show below that the experiments are revealing the compositeness of quarks in primons according to what was discussed in section 1 and in reference 1.

Reference 1 proposed, based on the data of Hofstadter and Herman[22], that the nucleons are composed of two layers of 3 primons in which a primon from the inner layer with another primon from the outer layer form a particular quark. In this way we can form all three quarks which, in turn, compose each nucleon.

What are DIS experiments seeing? Any particle Physics text states the following: *for low Q^2 the virtual photon γ^* probes the nucleon as a whole, for medium Q^2 γ^* sees three massless 'quarks´ and for large Q^2 γ^* probes the quark sea, and hadronic interactions show the constituent masses of quarks*. For example, P. Renton´s text Electroweak Interactions[23] on p. 316 says that "...we can picture the nucleon as composed of a core of hard $(x > 0.1)$ valence quarks with $\left(R^2\right)^{1/2} \approx 0.5\,fm$, surrounded by a large halo of sea quarks and gluons, the tails of which extend to infinity." Actually, this is quite a strange assertion because if the nucleon were composed of only three particles they would be found anywhere and not only near its center.

Considering the results on the nucleon spin, the proposal of reference 1 and the text of the above paragraph we clearly see that the **valence quarks do not have** $\left(R^2\right)^{1/2} \approx 0.5\,fm$ **because they are actually the very light primons of reference 1 and that is why we only measure half of the predicted spin by QCD**. **Constituent quarks, that is, true quarks have** $\left(R^2\right)^{1/2} \approx 0.5\,fm$**.** And what about the other three primons? They are very light and get smeared into the quark sea.

Therefore, the solution to the proton spin puzzle is the following: DIS are measuring the net S_z spin of the inner primons which is

$$\left(\frac{\hbar}{4}+\frac{\hbar}{4}-\frac{\hbar}{4}\right)=\frac{\hbar}{4} \tag{47}$$

but as it is well known by QCD only 60% of this goes to the nucleon spin and thus we obtain

$$0.6\frac{\hbar}{4}=0.3\frac{\hbar}{2} \tag{48}$$

This result clearly shows from QCD is a great theory and works very well with primons because color states are composed of supercolor states as is shown in reference 1.

When we take into account the outer layer of primons we pick up another $\hbar/4$ contribution and thus the total contribution is $0.6\left(\hbar/2\right)$ in accord with QCD.

Some important results that come out of this are: a) **the 'quarks´ seen by DIS are primons, actually;** b) **quarks are not light and are not pointlike, that is, constituent quarks are just the true quarks;** c) **bare (valence) quarks are primons and are pointlike;** c) **there is no missing spin when we take into account the two layers of primons;** d) **LHC will find three 'quarks´ near the center of the nucleon (that is, three primons, actually) and will find only half of the proton spin and, thus, will confirm what is said above.**

8. 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. As we see 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, and experiments may be misleading. For this purpose the future experiments should carefully compare the results of high, intermediate and low energy inelastic lepton scattering.

9. 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[24].

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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