Experimental Evidence of Non-Baryonic Dark Matter in High Energy Physics

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Abstract

If most of the universe is made of baryons, we encounter a serious contradiction in explaining the observed structure formulation. Therefore, we need non-baryonic dark matter to comprise the universe. In a previous paper, the present author proposed an infinite sub-layer quark model in which there exists an infinite number of up quark $q_u(\infty)$ and down quark $q_d(\infty)$ at an infinite sub-layer level. These quarks have non-baryon quantum number with one-half electric charge. Thus, $q_u(\infty)$ and $q_d(\infty)$ quarks are candidates for the non-baryonic dark matter. It is then shown that CP is violated only in the doublet of $q_u(\infty)$ and $q_d(\infty)$ quarks to account for the asymmetry of the number of particles and anti-particles in the present universe. It should be emphasized that if the internal space of $q_u(\infty)$ and $q_d(\infty)$ quarks in the first generation is a noncommutative geometry, CP violation can be explained without increasing the number of particles and generations. Thus, a pair of an infinite number of $q_u(\infty)$ and $q_d(\infty)$ quarks would be produced in the first moments after the Big Bang and form the hadrons including the nucleons and remain as the non-baryonic cold dark matter for all time. From the $q_f(\infty)$ quarks with the flavors $f = u$, d, s, c, t, and b, we compared our prediction value of the cross-section ratio R with the experimental values. We obtained the theoretical branching ratio $R = 15/4 = 3.75$ which is in good agreement with the experimental values from 12.00 GeV to 46.47 GeV in electron-positron annihilation into muon pairs and quark pairs.

Keywords

Non-Baryonic Dark Matter Non-Baryonic Quark Electron-Positron Annihilation

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1. Introduction

Our universe is made up of many different hierarchical clusters, such as quarks, nucleons (protons and neutrons), nuclei, atoms, molecules, gas clouds, planets, stars, galaxies, meta-galaxies, ad infinitum. As we move to the lower side on the hierarchy of such clusters, we hit the bottom of the hierarchy and find the smallest particles that exist, the ultimate building blocks of the universe. Indeed, the present author has proposed an infinite sub-layer quark model for the nucleon [1] and showed that there exists an infinite number of non-baryonic and half-electric charged $q_u(\infty)$ and $q_d(\infty) = \bar{q}_u(\infty) = q_u^{cp}(\infty)$ quarks at an infinite sub-layer level. The superscript CP means charge conjugation and parity transformation. The ultimate particle $q_u(\infty)$ has all one-half quantum numbers of spin $S = 1/2$, isospin $I = 1/2$, the third component of isospin $I_3 = 1/2$ and fractional electric charge $Q = (1/2)|e|$ where e is the electron charge. This is derived as follows: The proton (p) and the neutron (n) are made up of $q_u(1)$ and $q_d(1)$ quarks, so that $p = q_u(1)q_u(1)q_d(1)$ and $n = q_u(1)q_d(1)q_d(1)$. Furthermore, $q_u(1)$ and $q_d(1)$ quarks are made up of $q_u(1) = q_u(2)q_u(2)q_d(2)$ and $q_d(1) = q_u(2)q_d(2)q_d(2)$, etc. In summary, $q_u(N)$ and $q_d(N)$ quarks at level N are made up of $q_u(N+1)$ and $q_d(N+1)$ quarks at level $N+1$, such as $q_u(N) = (q_u(N+1), q_u(N+1), q_d(N+1))$ and $q_d(N) = (q_u(N+1), q_d(N+1), q_d(N+1))$ where $N = 1, 2, 3, \cdots, \infty$.

Here, the $q_u(N)$ and $q_d(N)$ quarks have quantum numbers of spin $S = 1/2$, isospin $I = 1/2$ third component of isospin $I_3 = \pm 1/2$, fractional electric charge $Q = \left[(1 \pm 3^N)/(2 \times 3^N) \right]|e|$, and baryon number $B = 1/3^N$. Thus, at $N = \infty$, the baryon number vanishes. The fractional electric charge is derived from the Gell-mann Nishijima formula, $Q = I_3 + B/2$ [2]. An infinite number of point-like quarks $q_u(\infty)$ with $Q = 1/2|e|$ and anti-quarks $q_d(\infty) = \bar{q}_u(\infty) = q_u^{cp}(\infty)$ with $Q = -1/2|e|$ are considered as constituting the nucleon. The ultimate $q_u(\infty)$ and $q_u^{cp}(\infty)$ quarks mean really the ancient Greek atoms, since they are indivisible.

In a previous paper [3], the present author proposed the shell or orbit model of an infinite number of quarks by considering the Cantor Set. That is, like the atom, in place of the positively charged nucleus and instead of negatively charged electrons, the infinite number sub-layer quarks were considered. At most outer orbit, there exist an infinite number of quarks and antiquarks having all half-quantum numbers.

We applied the Cantor set based our sub-layer model to the classical atomic model. The black hole was also applied to Bohr's classical model and some important results were obtained [4].

In our previous papers [5] [6] and in our book [7], by considering the internal structure of $q_u(\infty)$ and $q_d(\infty)$ quarks which is described by the $SU(2)$ noncommutative geometry, that is, a two-dimensional vector space over the complex Körper **C**, it is shown that CP is violated only in the doublet of $q_u(\infty)$ and $q_d(\infty)$ quarks in the first generation. It should be emphasized that CP

violation can be explained without increasing the number of particles and the second and the third generations.

In deep inelastic electron proton scattering at high energies, an infinite number of partons constituting the nucleon have been proposed [8] [9].

The parton is a fractionally charged and point-like particle. Therefore, the limit $q_u(\infty)$ and $q_u^{cp}(\infty)$ quarks are regarded as the partons. Furthermore, a point Dirac particle with charge $\pm 1/2e$ was already predicted in the total backward electron-proton scattering at fixed large four-momentum transfer q^2 [10].

In the following, we will apply an infinite sub-layer model for u and d quarks to c, s, b and t quarks and compare with the measurements in electron-positron annihilation into muon pairs and quark pairs.

2. Electron-Positron Annihilation into Muon Pairs and Quark Pairs

In electron-positron annihilation, $e^+e^- \to \gamma \to q_f(\infty)\bar{q}_f(\infty) \to \text{hadrons}$ process occurs through thephoton γ. R is defined as the ratio of the hadronic cross section to the muon cross section.

An infinite sublayer quark model is applied to q_f quarks with the flavors $f = u, d, s, c, t, b$.

The quantum numbers in the standard quark model are shown in Table 1.

$q_u(\infty)$ and $q_d(\infty)$ quarks belong to the first generation,

$q_s(\infty)$ and $q_c(\infty)$ quarks the second generation and $q_b(\infty)$ and $q_t(\infty)$ quarks the third generation.

The extended Gell-mann-Nishijima formula [2] is written as:

$$Q = I_3 + \frac{1}{2}(B + S + C + \mathcal{B} + T).\tag{1}$$

Table 2 is derived from Table 1 using both the baryon number $B = 1/3^N$ at $N = \infty$ and the above formula (1).

Table 1. Standard quark quantum numbers. q_u and q_d quarks belong to the first generation, q_s and q_c quarks the second generation and q_b and q_t quarks the third generation.

	q_u	q_d	q_s	q_c	q_b	q_t
Electric charge Q	+2/3	−1/3	−1/3	+2/3	−1/3	+2/3
Isospin I	+1/2	+1/2	0	0	0	0
Third component of isospin I_3	+1/2	−1/2	0	0	0	0
Baryon number B	+1/3	+1/3	+1/3	+1/3	+1/3	+1/3
Strangeness number S	0	0	−1	0	0	0
Charm number C	0	0	0	+1	0	0
Bottom number $\mathcal{B}$	0	0	0	0	−1	0
Top number T	0	0	0	0	0	+1

Table 2. Quark quantum numbers at an infinite sub-layer level. All quantum numbers are just one-half.

	$q_u(\infty)$	$q_d(\infty)$	$q_s(\infty)$	$q_c(\infty)$	$q_b(\infty)$	$q_t(\infty)$
Electric charge Q	1/2	−1/2	−1/2	1/2	−1/2	1/2
Isospin I	1/2	1/2	0	0	0	0
Third component of isospin I_3	1/2	−1/2	0	0	0	0
Baryon number B	0	0	0	0	0	0
Strange spin component S/2	0	0	−1/2	0	0	0
Charm spin component C/2	0	0	0	1/2	0	0
Bottom spin component $\mathcal{B}$/2	0	0	0	0	−1/2	0
Top spin component T/2	0	0	0	0	0	1/2

3. Electron-Positron Annihilation into Muon Pairs and Quark Pairs

The lowest order QED total cross-section for the process via a virtual photon (γ) $e^+e^- \to \gamma \to \mu^+\mu^-$ gives

$$\sigma = \frac{4\pi\alpha^2}{3\left(\sqrt{s}\right)^2} \tag{2}$$

where α is the fine structure constant and $\sqrt{s}$ is the center-of-mass energy [2].

We neglected the lepton masses. An e^+e^- annihilation can produce hadrons through a virtual photon (γ) and $e^+e^- \to \gamma \to q_f(\infty)\bar{q}_f(\infty) \to \text{hadrons}$.

We obtain the total cross section:

$$\sigma = \frac{4\pi\alpha^2}{3\left(\sqrt{s}\right)^2} Q_f^2 N_c \tag{3}$$

Here Q_f are quark charges for the flavors $f = u, d, s, c, b$ and t. N_c are the color charges c = red, green and blue and $N_c = 3$.

The cross section ratio R is written as:

$$R = \frac{\sigma\left(e^+e^- \to q_f(\infty)\bar{q}_f(\infty)\right)}{\sigma\left(e^+e^- \to \mu^+\mu^-\right)} = 3\sum_{q_f(\infty)} Q_{q_f(\infty)}^2 \tag{4}$$

Thus, from **Table 2**, we obtain:

$$R = 3\times\left[\left(Q_u(\infty)\right)^2 + \left(Q_d(\infty)\right)^2 + \left(Q_s(\infty)\right)^2 + \left(Q_c(\infty)\right)^2 + \left(Q_b(\infty)\right)^2\right]$$
$$= 3\times\left[\left(\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2\right] = \frac{15}{4} = 3.75. \tag{5}$$

Now, we compare our prediction value $R = 15/4 = 3.75$ with the measurements in electron-positron annihilation into muon pairs and quark pairs.

Data are summarized in **Table 3** for the entire PETRA energy region [11]. The predicted 5 quark value $R = 15/4 = 3.75$ is shown by the solid straight line in **Figure 1**.

As shown in **Figure 1**, the theoretical branching ratio $R = 15/4 = 3.75$ is in good agreement with the experimental values from 12.00 GeV to 46.47 GeV in electron-positron annihilation into muon pairs and quark pairs.
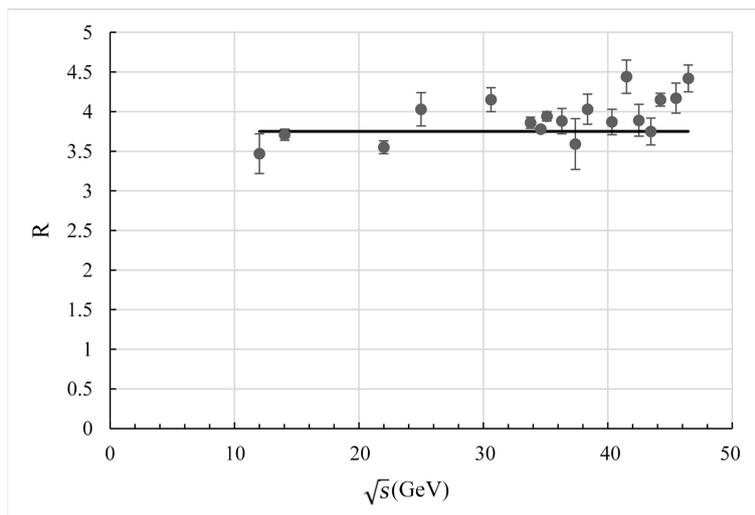

Figure 1. Prediction value R versus measurements from 12.00 GeV to 46.47 GeV.

Table 3. Measurements values R [11].

$\sqrt{s}$ (GeV)	R
12.00	3.47 ± 0.25
14.03	3.71 ± 0.07
21.99	3.55 ± 0.08
25.00	4.03 ± 0.21
30.61	4.15 ± 0.15
33.79	3.86 ± 0.07
34.61	3.78 ± 0.03
35.10	3.94 ± 0.06
36.31	3.88 ± 0.16
37.40	3.59 ± 0.32
38.38	4.03 ± 0.19
40.34	3.87 ± 0.16
41.50	4.44 ± 0.21
42.50	3.89 ± 0.20
43.46	3.75 ± 0.17
44.23	4.15 ± 0.08
45.48	4.17 ± 0.19
46.47	4.42 ± 0.17

4. Conclusion

An infinite sub-layer quark level was considered. These quarks will behave, as if they were lepton since the baryon number vanishes at the infinite sub-layer level. If most of the universe is in baryons, we encounter serious difficulties in explaining the observed structure formulation [12]. Therefore, the non-baryonic quarks are the candidates for the non-baryonic dark matter. The problem of dark matter is also discussed within the framework of extended gravity theory [13]. The prediction value R for our model is in good agreement with the measurements at high energies from 12.00 GeV to 46.47 GeV. Furthermore, if we consider one doublet in the first generation, it is shown that CP is violated via a noncommutative geometry. Thus, the infinite sub-layer quark level may be related to CP violation in the origin of the Universe accounting for the asymmetry of the number of particles and ant-particles in the present universe. Finally, it is concluded that an infinite number of $q(\infty)$ and $\bar{q}(\infty)$ quarks were created in the early universe after the Big Bang and are full of the present universe and form the non-baryonic dark matter.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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