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Evidence for Non-Baryonic Dark Matter

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Abstract

There exists an infinite number of quarks $u(\infty)$ and anti-quarks $\overline{u(\infty)}$ at an infinite sub-layer level. These particles are considered as the ultimate building blocks of the universe, since they are structure-less and absolutely stable. These particles are also regarded as the non-baryonic dark matter, since the baryon number is zero and the R_p-parity is -1. It is emphasized that super-symmetric particle, neutralino has also the R_p-parity of -1 and well known good cold dark matter candidate. In modern particle physics, all ordinary particles have the R_p-parity of $+1$, while both the ultimate quark $u(\infty)$ and neutralino have the R_p-parity of -1. This means that these particles can only be created or annihilated in pairs in reactions of ordinary particles. From electron-positron annihilation experiments at high energies, it is shown that the prediction value from the ultimate quark $u(\infty)$ is in good agreement with many ring-storage collider experiments.

Keywords

Non-Baryonic Dark Matter, Negative R_p-Parity, Neutralino, Electon-Positron Experiment

1. Introduction

In some previous papers [1] [2] [3] [4], the present author showed that there exists an infinite number of quark $u(\infty)$ and its anti-quark $\overline{u(\infty)}$ as the ultimate buiding blocks of the universe. The dark matter. leptons, quarks, gauge bosons and Higgs bosons are also composed of $u(\infty)$ and $\overline{u(\infty)}$ quarks. The $u(\infty)$ and $\overline{u(\infty)}$ quarks are good candidates for non-baryonic dark matter, since baryon number is zero and the R_p-parity is negative, that is, -1. The recent astronomical observations imply that the universe consists of 0.5% luminous matter like stars and galaxies, 4% ± 0.4% baryonic dark matter, 23% ± 3% non-baryonic dark

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matter and 73% ± 3% dark energy [5]-[10]. Thus the present universe is made of non-baryonic matter rather than baryonic dark matter. There are some models for dark matter [11]. For example, the candidate of baryonic dark matter is black holes, neutron stars and white dwarfs. As the non-baryonic dark matter, neutrino, axion and neutralino are considered [12]. Neutralino is derived from supersymmetric counterpart of neutrino. The lightest neutralino is the leading cold dark matter candidate, since it is absolutely stable and R_p-parity [13] is conserved. R_p-parity is defined with baryon number B, lepton number L and spin S, as

$$R_\mathrm{p} = (-1)^{3B+L+2S} \equiv (-1)^{3(B-L)+2S} \tag{1}$$

Supersymmetic particle has the R_p-parity of −1. The ultimate quark u(∞) has also the R_p-parity of −1, since $B = 0$, $L = 0$, $S = 1/2$ and the standard quark u has the R_p-parity of +1, because of $B = 1/3$, $L = 0$ and $S = 1/2$.

Thus all ordinary particles of the standard model have the R_p-parity of +1, while neutralino, superpartner of neutrino in supersymmetry has the negative R_p-parity of −1.

R_p-parity is a conserved multiplicative quantum number, therefore, the particle can only appear quadratically in the Lagrangian. This means the supersymmetric particles can only be produced in pairs. This particle is absolutely stable and there is no charged particle into which it can decay.

This fact is what makes the supersymmetric particle a good dark matter candidate.

Now, consider the ultimate quark u(∞) and its anti-quark $\overline{\mathrm{u}(\infty)}$ as non-baryonic dark matter candidates, since they are absolutely stable, similar to neutralino and the non-baryonic particles with the baryon number 0. A pair of an infinite number of u(∞) and $\overline{\mathrm{u}(\infty)}$ quarks would be produced in the early universe of the Big Bang and leave the right relic abundance to explain the observed dark matter. In the following, we will construct the infinite sub-layer quark model.

2. An Infinite Sub-Layer Quark Model

This is derived as follows: The proton (p) and the neutron (n) are made up of u(1) and d(1) quarks, so that p = u(1) u(1) d(1) and n = u(1) d(1) d(1). Furthermore, u(1) and d(1) quarks are made up of u(1) = u(2) u(2) d(2) and d(1) = u(2) d(2) d(2), etc. In summary, u(N) and d(N) quarks at level N are made up of u(N + 1) and d(N + 1) quarks at level N + 1, such as u(N) = (u(N + 1), u(N + 1), d(N + 1)) and d(N) = (u(N + 1), d(N + 1), d(N + 1)) where $N = 1, 2, 3, \cdots, \infty$.

Here, the u(N) and 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 $Q = \left[\left(1 \pm 3^N\right)/\left(2 \times 3^N\right)\right]|e|$, and baryon number $B = 1/3^N$. This is shown in Table 1.

3. Six Quarks at an Infinite Sub-Layer Quark Model

In the standard qurk model, there are six quarks, that is, up(u), down(d), strange(s), charm©, bottom(b) and top(t). Standard 6 quark quantum numbers are shown in **Table 2**.

Quantum numbers at an infinite sub-layer level are shown in **Table 3**.

In **Table 2**, it is shown that baryon number $B = 1/3$, R_p-parity = +1, electric charge $Q = -1/3$ or 2/3, while, in **Table 3**, $B = 0$, R_p-parity = −1 and $Q = \pm 1/2$. Thus, at an infinite sub-layer level, all quantum numbers are just one-half.

Table 1. Infinite sub-layer quark quantum numbers from $N = 0$ to $N = \infty$.

Level (N)	Symbol	Combination	S	B	I	I_3	Q
0	p(proton)	u(1) u(1) d(1)	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{2}$	$+\lvert e\rvert$
	n(neutron)	u(1) d(1) d(1)	$\frac{1}{2}$	1	$\frac{1}{2}$	$-\frac{1}{2}$	0
1	u(1)	u(2) u(2) d(2)	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{2}{3}\lvert e\rvert$
	d(1)	u(2) d(2) d(2)	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{3}\lvert e\rvert$
⋮	u(N)	u(N+ 1) u(N+ 1) d(N+ 1)	$\frac{1}{2}$	$\frac{1}{3^N}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1+3^N}{2\times 3^N}\lvert e\rvert$
N	d(N)	u(N+ 1) d(N+ 1) d(N+ 1)	$\frac{1}{2}$	$\frac{1}{3^N}$	$\frac{1}{2}$	$-\frac{1}{2}$	$\frac{1-3^N}{2\times 3^N}\lvert e\rvert$
⋮	u(∞)	Structure-less	$\frac{1}{2}$	0	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}\lvert e\rvert$
∞	$\mathrm{d}(\infty) = \overline{\mathrm{u}(\infty)}$	Structure-less	$\frac{1}{2}$	0	$\frac{1}{2}$	$-\frac{1}{2}$	$-\frac{1}{2}\lvert e\rvert$

Table 2. Additive quantum numbers of the quarks in the standard model. The subscript "L" indicates the left-handed particle.

	First family		Second family		Third family	
Flavors	d	u	s	c	b	t
R_p-parity	+1	+1	+1	+1	+1	+1
Baryon number B	1/3	1/3	1/3	1/3	1/3	1/3
Electric charge Q	−1/3	2/3	−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
Strangeness number S	0	0	−1	0	0	0
Charm number C	0	0	0	1	0	0
Bottomness number $\mathcal{B}$	0	0	0	0	−1	0
Topness number T	0	0	0	0	0	1
Third component of weak isospin $(t_3)_L$	−1/2	1/2	−1/2	1/2	−1/2	1/2

Table 3. Additive quantum numbers at an infinite sublayer level. All quantum number is just one-half.

	First family		Second family		Third family	
Flavors at an infinite sublayer level $N \to \infty$	d (∞)	u (∞)	s (∞)	c (∞)	b (∞)	t (∞)
R_p-parity	−1	−1	−1	−1	−1	−1
Baryon number B	0	0	0	0	0	0
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
Strangeness number spin $S/2$	0	0	−1/2	0	0	0
Charm number spin $C/2$	0	0	0	1/2	0	0
Bottomness number spin $\mathcal{B}/2$	0	0	0	0	−1/2	0
Topness number spin $T/2$	0	0	0	0	0	1/2
Third component of weak isospin $(t_3)_L$	−1/2	1/2	−1/2	1/2	−1/2	1/2

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

Now consider electron-positron annihilation via a virtual photon (γ).

This Feynman diagram is shown in **Figure 1**.

The lowest order QED differential cross-section for the process via a virtual photon (γ)

$$e^+e^- \to \gamma \to \mu^+\mu^- \quad \text{gives}$$

$$\mathrm{d}\sigma = \frac{\pi\alpha^2}{2\left(\sqrt{s}\right)^2}\left(1+\cos^2\theta\right)\mathrm{d}\left(\cos\theta\right) \tag{2}$$

where θ is the angle of emission of muons in the CMS(center of mass) system, α is the fine structure constant, and $\sqrt{s}$ is the center-of-mass energy [14].

The total cross-section is written as

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

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

We obtain the total cross-section

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

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 $N_c = 3$.

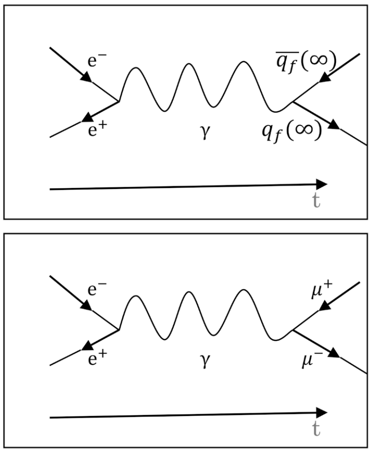

Figure 1. Electron-positron annihilation into quark pairs ($e^+e^- \to \gamma \to q_f(\infty)\overline{q_f}(\infty)$) and muon pairs ($e^+e^- \to \gamma \to \mu^+\mu^-$) via virtual photon γ.

The cross-section ratio R is written as

$$R = \frac{\sigma\left(e^+e^- \to q_f(\infty)\overline{q_f}(\infty)\right)}{\sigma\left(e^+e^- \to \mu^+\mu^-\right)} = 3\sum_{q_f(\infty)} Q^2_{q_f(\infty)} \tag{5}$$

We consider the following generalized Gell-Mann-Nishijima formula [16],

$$Q = I_3 + \frac{1}{2}\left(B + S + C + \mathcal{B} + T\right). \tag{6}$$

From the standard quark model in **Table 2**, we obtain the following cross-section ratio R for u, d, s, c and b quarks:

$$\begin{aligned} R &= 3\times\left[Q_u^2 + Q_d^2 + Q_s^2 + Q_c^2 + Q_b^2\right] \\ &= 3\times\left[\left(\frac{2}{3}\right)^2 + \left(-\frac{1}{3}\right)^2 + \left(-\frac{1}{3}\right)^2 + \left(\frac{2}{3}\right)^2 + \left(-\frac{1}{3}\right)^2\right] \\ &= \frac{11}{3} \end{aligned}$$

for u, d, s, c, b quarks.

The prediction value R = 11/3 was already compared with various experiments [15]-[20].

Now consider u(∞), d(∞), s(∞), c(∞) and t(∞) quarks at an infinite sub-layer level.

From **Table 3**, we obtain the following theoretical branching ratio R = 15/4 = 3.75

$$\begin{aligned} R &= 3\times\left[Q_u^2 + Q_d^2 + Q_s^2 + Q_c^2 + Q_b^2\right] \\ &= 3\times\left[\left(\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2 + \left(\frac{1}{2}\right)^2 + \left(-\frac{1}{2}\right)^2\right] \\ &= \frac{15}{4} = 3.75 \end{aligned}$$

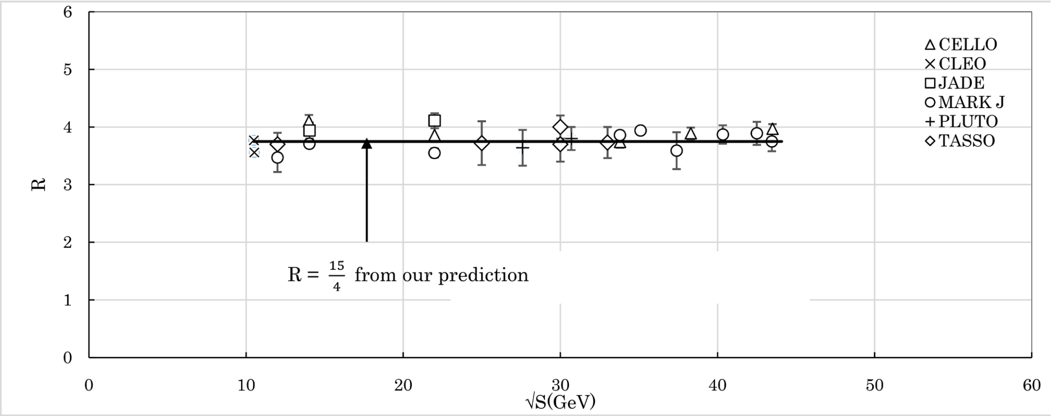

Figure 2. Various experimental values R from 10.49 GeV to 43.46 GeV versus prediction value $R = 15/4 = 3.75$.

This prediction value is compared with various storage-ring collider experiments from the CELLO [21], CLEO [22], JADE [23], MARK J [24], PLUTO [25] and TASSO [26] Collaborations. This is shown in **Figure 2**.

For clarity, all data in the references are not appearing in the figure.

Thus, the prediction value from the ultimate quark u(∞) agrees well with many ring-storage collider experiments.

The third order QCD radiation correction formula is written as

$$R = 3\sum_{q_f} Q_{q_f}^2 \left[1+\left(\frac{\alpha_s(s)}{\pi}\right)+1.4092\left(\frac{\alpha_s(s)}{\pi}\right)^2-12.8046\left(\frac{\alpha_s(s)}{\pi}\right)^3\right] \quad (7)$$

and gives

$R(34\ \text{GeV}) = 11/3(1.056 \pm 0.008) = 3.87 \pm 0.03$, thus the QCD (Quantum Chromodynamics) correction increases the predicted value by ~5% [27] which agrees with our predicated value $R = 15/4 = 3.75$ better than the naïve 5 quark value $R = 11/3 = 3.67$.

5. Conclusions and Discussions

As the ultimate building blocks of the universe, there exists an infinite number of structure-less quarks u(∞) and anti-quarks $\overline{\mathrm{u}(\infty)}$ at an infinite sub-layer level. These particles have the R_p-parity of −1, since the baryon number is zero. Similarly, supersymmetric particles have also R_p-parity of −1. They are created and annihilated in pairs. For all ordinary particles, the R_p-parity is +1. u(∞) and $\overline{\mathrm{u}(\infty)}$ quarks and the lightest supersymmetric particle, especially, neutralino are good candidates for non-baryonic dark matter, since they are absolutely stable.

The ultimate u(∞) and $\overline{\mathrm{u}(\infty)}$ quarks are regarded as partons [28] [29] and non-baryonic dark matter [3].

To validate our model, we examined electron-positron annihilation into muon pairs and quark pairs in high-energy physics. As shown in **Figure 1**, the prediction value is in good agreement with the experiments. A pair of u(∞) and $\overline{\mathrm{u}(\infty)}$ quarks would be produced in the first and early universe after the Big

Bang and then remains abundantly as the non-baryonic dark matter for all time , stable against decay. It is emphasized that CP is violated in the hot early universe of the Big Bang to account for the asymmetry of the number of particles and anti-particles [30]. This is explained by an SU(2) non-commutative geometry [30] [31] [32]. As shown in **Table 2** and **Table 3**, there are three families. In a previous paper, we showed that there are just four families [33]. This is derived from Charge, Parity and Time(CPT) transformation and the $SU(2)_L xU(1)$ gauge theoty. We assumed that the second, third and fourth families are the excited states of the first family. Therefore, the u(∞) and $\overline{u(\infty)}$ quarks are the ultimate particles in the universe. It is interesting to note that in **Table 3**, all quntum nmbers are just one-half including the electric charge. Thus, "Nature is simple and beautiful. The truth lies in its beauty". CP violation in β decay and preon model was also discussed in the references [34] [35] [36] [37]. We showd that gauge bosons, leptons and Higgs bosons are composed of the u(∞) and $\overline{u(\infty)}$ [4]. Especially, if the electron is made up of the u(∞) and $\overline{u(\infty)}$ quarks and CP is violated, then the self-energy of the electron is removed. It is not necessary to consider renormalization theory [38].

Higgs bosons are also made of the ultimate quarks, and we replace the Higgs potential with the gravitational potential. it was shown that the masses are produced and Einstein's cosmological constant was derived [39]. By considering the n-th order T product Green's function in the path-integral representation, we can construct a quantization theory including the cosmological constant without the gravitational field [40] [41].

Recently, there has been great interest in gravitational waves, dark matter and dark energy. The dark matter effects were discussed within the framework of the extended gravity theories [42] [43].

The problem of future gravitational waves in astronomy was also discussed [44].

We proposed theoretically the possibility of gravitational wave lasers [45].

Finally, it is concluded that an infinite number of u(∞) and $\overline{u(\infty)}$ quarks was created in the early universe after the Big Bang, and leaves the right relic abundance to account for the observed non-baryonic dark matter. We compared it with high-energy experimental results to obtain validation of our model.

As can be seen from **Figure 2**, the existence of non-baryonic dark matter has been confirmed.

Conflicts of Interest

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

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