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Formation of Nonaquarks and Mysteries of Antimatter and Dark Matter

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Abstract

Two biggest mysteries that have been puzzling scientists for many decades are the baryon asymmetry and the origin of dark matter. To solve why the present universe is significantly missing antimatter but is fully filled with dark matter, we have examined how hadronic particles were produced from combinations of quarks and antiquarks in the early universe after the end of the quark epoch. It is shown that, in addition to the normal baryons formed by a direct color-charge binding of three quarks, a special type of superhadron baryons, called to nonaquarks, could be formed via a two-level color-charge binding of three quarks and six antiquarks in the early universe. The lowest energy state neutral nonaquarks, named as superons, which are formed from the first-generation (*i.e.*, up and down) or lowest state quarks and antiquarks can be an appropriate candidate of dark matter particles—weakly interacting massive particles (WIMPs). These nonaquarks formed from the combinations of quarks with twice number of antiquarks provide us a possible solution for both the mysteries of the baryon asymmetry and dark matter's origin.

Keywords

Nonaquark, Antimatter, Dark Matter, Quark, Particle

1. Introduction

Antimatter is a type of matter made of antiparticles, which have same mass but opposite electric charge to the corresponding particles. It is found to be extremely rare in the present universe, but according to the Big Bang theory, matter and antimatter should be created in equal amounts in the early universe. With the equal amounts of matter and antimatter, stars, planets, and galaxies should not be formed. Why the universe does not have equal parts of matter and antimatter at present or why the universe behaves baryon asymmetry is one of the most significant unsolved problems in physics and cosmology. Where did all the antimatter go? Some prevailing theories of missing antimatter include antimatter regions formed in the baryon-dominated universe [1], baryogenesis in the baryon-symmetric universe [2], and so on.

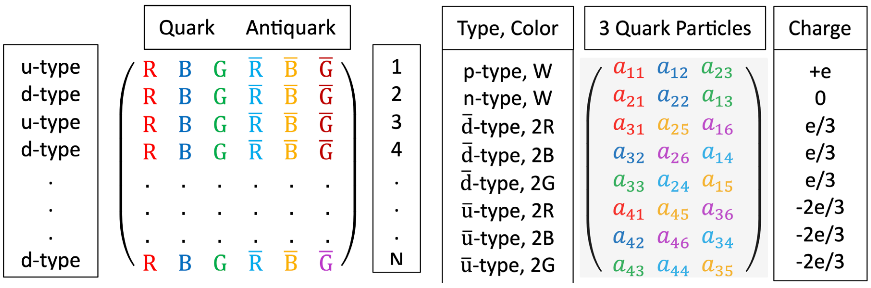
Dark matter is a hypothetical form of matter that interacts with matter via only the gravitational interaction, not emitting, absorbing and reflecting light so that it is neutral and invisible. Its mass abundance is about five times that of matter in the universe. Without dark matter, galaxies would not hold their matter together, galactic clusters would not bend light as much as observed, and cosmic microwave background (CMB) radiation would not have observationally consistent perturbations. One of the leading theories suggests that dark matter is composed of weakly interacting massive particles (WIMPs) [3]. The presence or origin of dark matter in the universe is another unsolved mystery in physics and cosmology.

This paper provides an innovative insight into the mysteries of antimatter and dark matter in the universe. It shows how quarks combine with twice number of antiquarks to form a special type of superhadron baryon, called to nonaquarks, in the early universe, so that provides us a possible candidate of dark matter particles. This work potentially solves both the mysteries of why the present universe is significantly missing antimatter but is fully filled with dark matter.

2. Quark-Gluon Plasma in the Early Universe

Based on the standard Big Bang cosmology, our universe originated from a hot, dense and extremely small state around 13.8 billion years ago [4]. It has evolved through a sequence of epochs such as inflation, quark, hadron, and nucleosynthesis epochs to star, galaxy, and cluster formations, and then to the present status and further to the heat death of the universe. The quark epoch refers to the period in the early universe, started roughly at 1 picosecond after the Big Bang when the electroweak interaction separated into the weak interaction and the electromagnetic interaction and lasted until about 1 micro-second [5]. During this period, the universe was extremely hot and dense, filling with a quark-gluon plasma, which contains free quarks, gluons, leptons and their antiparticles as building blocks of the universe and force carriers [6]. At the end of the quark epoch, the universe cooled down to the point so that quarks including antiquarks started to bind or combine via the strong force or color-color charge interaction and formed hadrons and other possible types of particles such as dark matter particles [7], e.g. the hexaquark (uuddss) [8] or nonaquarks of this work [9]. After the quark epoch, the hadron epoch started. The hadron epoch ended round at 1 second after the Big Bang.

Here, we consider a hot, dense quark-gluon plasma that contains $3N$ quarks with three types of color charges to be labelled red (R), blue (B), and green (G) and $3N$ corresponding antiquarks with three types of color charges to be labelled antired ($\bar{\mathrm{R}}$), antiblue ($\bar{\mathrm{B}}$), and antigreen ($\bar{\mathrm{G}}$). Like the early universe at the quark epoch, all the quarks and antiquarks are free without yet binding together to form hadrons. Here, N is a big number. For easy to count each of them, we order or arrange all the $3N$ quarks and $3N$ antiquarks into an $N \times 6$ matrix according to their colors and types in **Figure 1(a)**. The $6N$ matrix's components are denoted as a_{ij} with $i = 1, 2, \cdots, N$ and $j = 1, 2, \cdots, 6$. Each component of the matrix represents a quark or an antiquark with a particular color and a particular type or flavor such as a_{12} representing a blue-color up-type quark and a_{24} representing an antired-color down-type antiquark. To the standard model of particle physics, the up-type of quarks, U, includes the up (u), charm (c), and top (t) quarks with electric charge $+2e/3$, U = {u, c, t}, while the down-type of quarks, D, includes the down (d), strange (s), and bottom (b) quarks with electric charge $-e/3$, D = {d, s, b}. Here, $e = 1.6 \times 10^{-19}$ C is the fundamental unit of electric charge. To the new two-flavor multi-excitation model of quarks, they are U = {u_0, u_1, u_2, u_3, …} and D = {d_0, d_1, d_2, d_3, …} [10]-[14]. This new quark model considers the heavy quarks: c, s, t, and b of the standard model to be the second and third excited states of up and down quarks.



(a) (b)

Figure 1. (a) Left panel: a sketch of an $N \times 6$ matrix that arranges the $3N$ quarks and $3N$ antiquarks according to their colors and types. (b) Right panel: a sketch of an 8 × 3 matrix that shows eight typical particles (two normal baryons and six superquarks) formed by combining the twelve quarks and twelve antiquarks given in the first four rows of **Figure 1(a)**. The first two rows form two-type (proton-type and neutron-type) and color-neutral normal baryon particles, while the third through eighth rows form two-type (anti-down type and anti-up type) three-color (2R, 2B, 2G) superquarks. Here, we call them superquarks because they have non-neutral color charges and fractional electric charges like normal quarks.

The two-flavor multi-excitation quark model was recently developed by the author based on his innovative thoughts and creative ideas that nature consists of four fundamental elements (e.g., radiation, mass, electric charge, and color charge), the weak force is an interaction between electric and color charges and occurs inside quarks, and quarks have only two flavors but multiple excited states. Decays of a quark result from the internal weak interaction between electric and color charges inside the quark. Excitations of a quark result also from the external strong interaction between color charges with other quarks. Quarks change their states via emitting or absorbing quark-antiquark pairs. There are in maximum eight possible ways for a quark to combine and/or annihilate with an antiquark to form a particle with various types, including mesons, leptons, gluons, photons, and Weyl fermions. Combinations of quarks and antiquarks up to the third excited states can form more different particles. In collisions, leptons would be disintegrated into quarks and antiquarks, which get excited and recombine to form other particles. Collisions of hadrons would excite their quarks and form also various other particles. The higher the energy of collisions is, the more particles are generated.

After the quark epoch ended, the universe cooled down to a point and switched into the hadron epoch, at which quarks and antiquarks with non-zero color charges started to bind together and form colorless hadrons and antihadrons such as protons, neutrons, and their antiparticles. The hadron epoch started at around 10^{-6} seconds and lasted until about 1 second after the Big Bang.

3. Color Charges of Quarks and Color Neutrality of Hadrons

In particle physics, color describes a fundamental property of quarks and gluons, related to the strong force [15]. These colors are not related to the visible colors but are types of charges. Quarks and antiquarks are bounded to form hadrons and antihadrons via the color-color charge interaction. Hadrons and antihadrons are color neutral, meaning that each of them has total color charges to be zero [16]. Conventionally, a combination of two quarks, when one is quark and another is antiquark and their colors are opposite (*i.e.* anti each other, e.g.: $(R,\overline{R})$, $(B,\overline{B})$, $(G,\overline{G})$), forms a colorless hadron meson such as pions; a combination of three quarks with colors (R,B,G) forms a colorless hadron baryon such as protons and neutrons; and a combination of three antiquarks $(\overline{R},\overline{B},\overline{G})$ forms a colorless hadron antibaryon such as antiprotons and antineutrons. In a hot, dense quark-gluon plasma, free quarks and antiquarks are supposed to be combined randomly. All mesons are unstable and decay into others. Proton is the lowest state of baryons and stable. Other formed baryons decay towards the stable one.

Many more other combinations of quarks and antiquarks such as $(R,\overline{B})$, $(R,\overline{G})$, $(B,\overline{R})$, $(B,\overline{G})$, $(G,\overline{R})$, and $(G,\overline{B})$ or $(R,\overline{B},\overline{G})$, $(B,\overline{G},\overline{R})$, $(G,\overline{R},\overline{B})$, $(R,B,\overline{G})$, $(B,G,\overline{R})$, and $(G,R,\overline{B})$ do not form the normal mesons or baryons, because the formed ones still hold non-zero color charges. They need to combine further with more quarks and/or antiquarks to form color-neutral and thus observable exotic particles. For instance, combining of $(R,\overline{B})$ with $(B,\overline{R})$ forms a four-quark meson $(R,B,\overline{R},\overline{B})$, called to tetraquark, and combining of $(R,B,\overline{G})$ with two quarks of color (G) forms an exotic five-quark baryon $(R,B,G,G,\overline{G})$, called to pentaquark, which consists of a normal baryon and a normal meson, and many so on. In this study, we surprisingly found that combining of $(R,\overline{B},\overline{G})$, $(B,\overline{G},\overline{R})$ and $(G,\overline{R},\overline{B})$ could form an interesting exotic and superhadron baryon $(R,B,G,\overline{R},\overline{B},\overline{G},\overline{R},\overline{B},\overline{G})$, called to nonaquark. It may exist a stable state, when their quarks and antiquarks are the first-generation or the lowest states like those in protons or neutrons.

The sum of a color and its anti-color or the sum of red, blue, and green colors or the sum of antired, antiblue, and antigreen colors results in a colorless or color-neutral state with a net color charge of zero. Therefore, in particle physics, that a combination of red with antired ($\mathrm{R},\overline{\mathrm{R}}$), blue with antiblue ($\mathrm{B},\overline{\mathrm{B}}$), green with antigreen ($\mathrm{G},\overline{\mathrm{G}}$), red with blue and green ($\mathrm{R},\mathrm{B},\mathrm{G}$), or antired with antiblue and antigreen ($\overline{\mathrm{R}},\overline{\mathrm{B}},\overline{\mathrm{G}}$) equals zero signifies that they cancel out their colors to create a colorless state with a zero net color charge. This is similar the combining positive and negative electric charges to get an electrically neutral state with a zero net electric charge (e.g., electron-positron annihilation). As mesons, baryons, and antibaryons do not have net color charges, we have color neutrality conditions or law of color charges: $\mathrm{R}+\overline{\mathrm{R}}=0$, $\mathrm{B}+\overline{\mathrm{B}}=0$, $\mathrm{G}+\overline{\mathrm{G}}=0$, $\mathrm{R}+\mathrm{B}+\mathrm{G}=0$, and $\overline{\mathrm{R}}+\overline{\mathrm{B}}+\overline{\mathrm{G}}=0$. Color neutrality refers to that only color-neutral particles can exist in isolation or independently [17]. Color confinement refers to that particles with colors or anticolors cannot be observed alone [18].

Based on the color neutrality conditions, we can have more derived relations between colors and anticolors: $\overline{\mathrm{R}}=-\mathrm{R}$, $\overline{\mathrm{B}}=-\mathrm{B}$, $\overline{\mathrm{G}}=-\mathrm{G}$, $\mathrm{R}=-\mathrm{B}-\mathrm{G}=\overline{\mathrm{B}}+\overline{\mathrm{G}}$ or $\mathrm{R}+\overline{\mathrm{B}}+\overline{\mathrm{G}}=2\mathrm{R}$, $\mathrm{B}=-\mathrm{G}-\mathrm{R}=\overline{\mathrm{G}}+\overline{\mathrm{R}}$ or $\mathrm{B}+\overline{\mathrm{G}}+\overline{\mathrm{R}}=2\mathrm{B}$, and $\mathrm{G}=-\mathrm{R}-\mathrm{B}=\overline{\mathrm{R}}+\overline{\mathrm{B}}$ or $\mathrm{G}+\overline{\mathrm{R}}+\overline{\mathrm{B}}=2\mathrm{B}$. Here, the colors 2R, 2B, 2G refer to doubles or twice amounts of color charges. Therefore, combining a quark of red color with two antiquarks of antiblue and antigreen colors forms a particle of double red color (or 2R); combining a quark of blue color with two antiquarks of antigreen and antired colors forms a particle of double blue color (or 2B); and combining a quark of green color with two antiquarks of antired and antiblue colors forms a particle of double green color (or 2G). As their electric charges are all fractional and their color charges are doubled, we call them as superquarks. They have color charges doubled and hence are bounded more tightly and strongly in more distance.

Mathematically, color charge is described by the representation theory of the SU(3) group. Color neutral particles belong to the singlet representation, and colorful quarks or superquarks belong to the triplet representations [17] [18]. In the author's newly developed four-element theory of nature, color and electric charges are two forms of imaginary energies, while mass and radiation are two forms of real energies [12].

4. Formation of Baryons and Superquarks

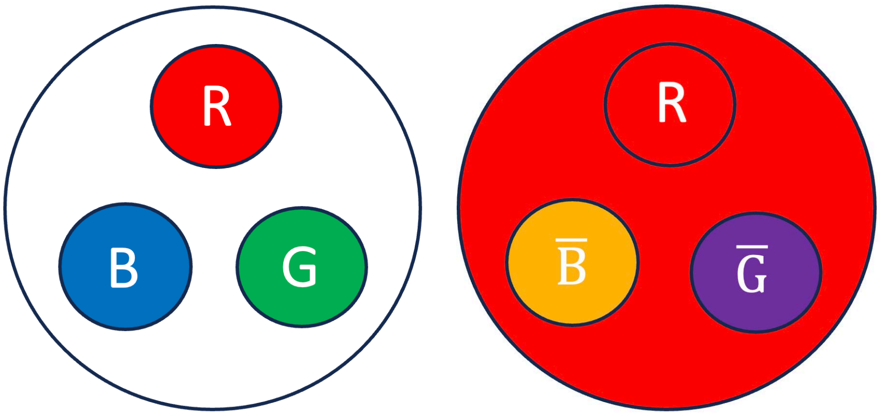
Now, we propose a new way or approach of quark and/or antiquark combinations to form non-zero color charge superquarks and then colorless superhadron baryons in the next section under either the standard model of particle physics (SM) or the two-flavor multi-excitation model of quarks [10]-[14]. This way or approach involves two steps of combinations. The first step includes: i) a combination of one quark with color R and two antiquarks with colors $\overline{\mathrm{B}}$ and $\overline{\mathrm{G}}$ to form a superquark with color double red (2R), ii) a combination of one quark with color B and two antiquarks with colors $\overline{\mathrm{G}}$ and $\overline{\mathrm{R}}$ to form a superquark with color double blue (2B), and iii) a combination of one quark with color G and two antiquarks with colors $\overline{\mathrm{R}}$ and $\overline{\mathrm{B}}$ to form a superquark with color double green (2G). Here, we have applied the color neutrality relations.

The second step is the combination of the formed three superquarks with colors being 2R, 2B, and 2G, respectively, to form a colorless superhadron baryon. As a superquark is composed of one quark and two antiquarks, a superhadron baryon, formed from a combination of three superquarks, is composed of three quarks and six antiquarks. We call it to nonaquark. A nonaquark binds three quarks and six antiquarks in a two-level or layered color-charge binding structure. The double red, blue or green color refers to that a superquark contains color charges twice amounts of that of a quark. We may use terms: di-red, di-blue, and di-green to refer to the double color charges (2R, 2B, and 2G).

Figure 1(b) specifies how superquarks are formed from combinations of one quark with two antiquarks $\left(\mathrm{q}\overline{\mathrm{q}}\overline{\mathrm{q}}\right)$ as well as how normal baryons are formed from simple color charge combinations of three quarks (qqq). For simple, we first consider the combinations of **Figure 1(a)**'s first four rows' twelve quarks and twelve antiquarks, which can form: (1) six superquarks from the six quarks and twelve antiquarks and (2) two normal baryon particles from the left six quarks. The row one of **Figure 1(b)** gives a combination of two up-type red and blue quarks with one down-type green quark $\left(a_{11}, a_{12}, a_{23}\right)$ to form a color-neutral (denoted W) proton-type normal baryon particle with electric charge $+e$, P^{+} = (UUD). The row two of **Figure 1(b)** gives a combination of two down-type red and blue quarks with one up-type green quark $\left(a_{21}, a_{22}, a_{13}\right)$ to form a color-neutral (denoted W) neutron-type normal baryon particle with zero electric charge, P^{0} = (UDD).

The row three of **Figure 1(b)**combines one up-type red quark with one down-type antiblue antiquark and one up-type antigreen antiquark $\left(a_{31}, a_{25}, a_{16}\right)$ to form a double red (or 2R) antidown-type superquark with electric charge $+e/3$. The row four of **Figure 1(b)** combines one up-type blue quark with one down-type antigreen antiquark and one up-type antired antiquark $\left(a_{32}, a_{26}, a_{14}\right)$ to form a double blue (or 2B) antidown-type superquark with electric charge $+e/3$. The row five of **Figure 1(b)** combines one up-type green quark with one down-type antired antiquark and one up-type antiblue antiquark $\left(a_{33}, a_{24}, a_{15}\right)$ to form a double green (or 2G) antidown-type superquark with electric charge $+e/3$. Similarly, the rows six through eight of **Figure 1(b)** combine one quark with two antiquarks to form three antiup-type superquarks, $\left(a_{41}, a_{45}, a_{36}\right)$, $\left(a_{43}, a_{46}, a_{34}\right)$, $\left(a_{43}, a_{44}, a_{35}\right)$, with electric charge to be $-2e/3$ and colors to be double red (or 2R), double blue (or 2B), and double green (or 2G), respectively. Here, the row subscript $i =$ odd numbers refers to the quark to be the up-type; the row subscript $i =$ even numbers refers to the quark to be the down-type; and the collum subscript $j = 1, 2, 3, 4, 5$ or 6 refers to the color of the quark to be $\mathrm{R}, \mathrm{B}, \mathrm{G}, \overline{\mathrm{R}}, \overline{\mathrm{B}}$ or $\overline{\mathrm{G}}$. Combining the first 4 rows of **Figure 1(a)**'s 12 quarks and 12 antiquarks, we can form 2 normal baryon particles and 6 superquarks (or 2 nonaquarks). Combining all the N rows of **Figure 1(a)**'s $3N$ quarks and $3N$ antiquarks, we can form $N/2$ normal baryon particles and $3N/2$ superquarks (or $N/2$ nonaquarks).

Figure 2(a) sketches a color-neutral normal baryon formed by combining three quarks with colors of R, B, and G, respectively. For example, a combination of two up-type red and blue quarks with one down-type green quark forms a proton-type baryon $P^+ = (UUD)$. Its lowest state is proton $p^+ = (uud)$ under the standard model or $p^+ = (u_0 u_1 d_0)$ under the two-flavor multi-excitation model of quarks. **Figure 2(b)** sketches, as an example, a color 2R superquark formed by combining one quark and two antiquarks with colors of R, $\bar{B}$, and $\bar{G}$, respectively. Here, we refer to it as a superquark because it has non-zero color charges and fractional electric charges, like a quark. There are two-types of superquarks according to their electric charges: (1) the antidown-type superquark with electric charges $+e/3$ and (2) the antiup-type superquark with electric charges $-2e/3$.



(a) (b)

Figure 2. (a) Left panel: a sketch of a color-neutral baryon particle that is formed by combining three quarks with colors to be R, B, and G, respectively. (b) Right panel: a sketch of a superquark with color 2R (or di-red) that is formed by combining one quark and two antiquarks with colors to be R, $\bar{B}$, and $\bar{G}$, respectively. We can have similar sketches for the color di-blue (2B) and di-green (2G) superquarks.

5. Formation of Nonaquarks

Figure 3 sketches how a color-neutral nonaquark is formed from a combination of three superquarks with colors to be di-red, di-blue, and di-green (*i.e.*, 2R, 2B, and 2G), respectively. From above detailed six (three antidown-type and three antiup-type) superquarks listed in the row three through row eight of **Figure 1(b)**, two nonaquarks can be formed. How the six superquarks combine to form two nonaquarks, there are two ways or cases, shown as follows.

Case I: a combination of two antidown-type superquarks with one antiup-type superquark forms a color-neutral nonaquark with electric charge to be zero (denoted by S^0) and a combination of one antidown-type superquark with two antiup-type superquarks forms a color-neutral nonaquark with electric charge to be $-e$ (denoted by S^-). Case II: a combination of three antidown-type superquarks forms a color-neutral nonaquark with electric charge to be $+e$ (denoted by S^+) and a combination of three antiup-type superquarks forms a color-neutral nonaquark with electric charge to be $-2e$ (denoted by S^{--}). Therefore, the four types of nonaquarks formed from the two-types of superquarks, which are made from three quarks and six antiquarks, are $\mathrm{S}^0, \mathrm{S}^-, \mathrm{S}^+, \mathrm{S}^{--}$. As the probability of Case-I's (mix type) combinations is much higher than that of Case-II's (pure type) combinations, we have that the nonaquarks S^0 and S^- are more likely produced than the nonaquarks S^+ and S^{--}.

In fact, formations of the normal baryons shown above also have similar two cases. The combinations of quarks shown in the first two rows of **Figure 1(b)** belong to the Case I. The Case II refers to the rare (or pure type) combination of three up-type red, blue, and green quarks (a_{11}, a_{12}, a_{13}) that forms those rarely discovered baryons with electric charge $+2e$ such as $\Delta^{++}, \Sigma_c^{*++}, \Xi_{cc}^{++}, \Omega_{ccc}^{++}$, etc. and the rare (or pure type) combination of three down-type red, blue, and green quarks (a_{21}, a_{22}, a_{23}) that forms those rarely discovered baryons with electric charge $-e$ such as $\Delta^-, \Sigma^-, \Xi^-, \Omega^-, \Omega_{bbb}^-$, etc. The four types of color-neutral normal baryons formed from combinations of three quarks with color charges of R, B, and G have electric charges of $+e$, 0, $-e$, and $+2e$ (denoted by $\mathrm{P}^+, \mathrm{P}^0, \mathrm{P}^-, \mathrm{P}^{++}$), in which P^+ and P^0 are more likely formed (Case I) than P^- and P^{++} (Case II).

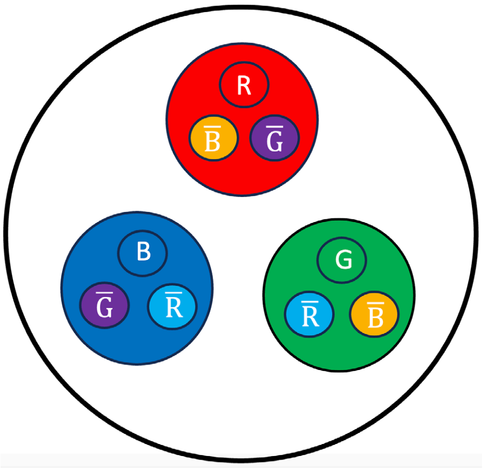
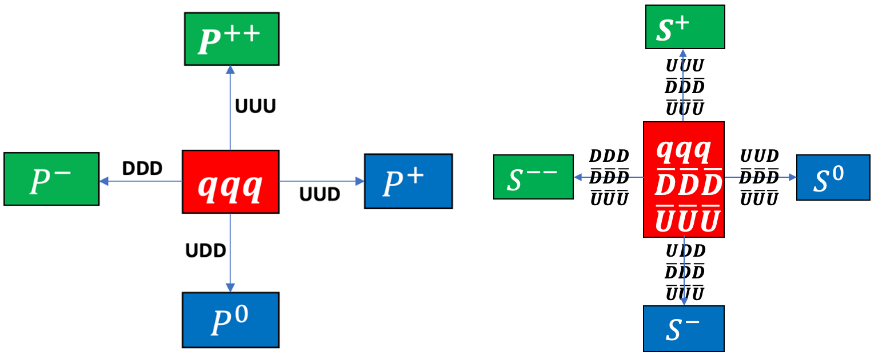


Figure 3. A sketch of a colorless superhadron baryon (two-level color-charge bound nonaquark). It is formed by combining three superquarks with colors to be 2R, 2B, and 2G, respectively. Each superquark is formed by combining one quark with two antiquarks.

The four types of color-neutral nonaquarks formed from the combinations of three superquarks with color charges 2R, 2B, and 2G, respectively, have electric charges of 0, $-e$, e, and $-2e$ (denoted by $\mathrm{S}^0, \mathrm{S}^-, \mathrm{S}^+, \mathrm{S}^{--}$), in which S^0 and S^- are likely formed (Case I). The quark compositions of the four-type normal baryons are $\mathrm{P}^+ = (\mathrm{UUD})$, $\mathrm{P}^0 = (\mathrm{UDD})$, $\mathrm{P}^{++} = (\mathrm{UUU})$, and $\mathrm{P}^- = (\mathrm{DDD})$. Particles $\Sigma_c^{++} = (\mathrm{uuc})$, $p^+ = (\mathrm{uud})$, $\Lambda^0 = (\mathrm{uds})$ and $\Sigma^- = (\mathrm{dds})$ are typical examples of these four-type normal baryons. The quark compositions of the four-type nonaquarks are $\mathrm{S}^0 = (\mathrm{UUD}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{U}}\bar{\mathrm{U}}\bar{\mathrm{U}})$, $\mathrm{S}^- = (\mathrm{UDD}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{U}}\bar{\mathrm{U}}\bar{\mathrm{U}})$, $\mathrm{S}^+ = (\mathrm{UUU}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{U}}\bar{\mathrm{U}}\bar{\mathrm{U}})$, and $\mathrm{S}^{--} = (\mathrm{DDD}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{D}}\bar{\mathrm{U}}\bar{\mathrm{U}}\bar{\mathrm{U}})$. The three quarks and six antiquarks of the four-type nonaquarks are structured as shown in **Figure 3** or grouped as $\mathrm{S}^0 = (\mathrm{U}\bar{\mathrm{D}}\bar{\mathrm{U}}, \mathrm{U}\bar{\mathrm{D}}\bar{\mathrm{U}}, \mathrm{D}\bar{\mathrm{D}}\bar{\mathrm{U}})$, $\mathrm{S}^- = (\mathrm{U}\bar{\mathrm{D}}\bar{\mathrm{U}}, \mathrm{D}\bar{\mathrm{D}}\bar{\mathrm{U}}, \mathrm{D}\bar{\mathrm{D}}\bar{\mathrm{U}})$,

$S^{+} = \left(U\bar{D}\bar{U}, U\bar{D}\bar{U}, U\bar{D}\bar{U}\right)$, and $S^{--} = \left(D\bar{D}\bar{U}, D\bar{D}\bar{U}, D\bar{D}\bar{U}\right)$. Figure 4(a) shows the four types of normal baryons that are formed from combinations of three quarks. Figure 4(b) shows the four types of nonaquarks that are formed from combinations of three superquarks.



(a) (b)

Figure 4. (a) Left panel: the four types of normal baryons that are formed from combinations of three quarks. They have electric charges to be $+e$, 0, $-e$, and $-2e$, respectively. (b) Right panel: the four types of nonaquarks that are formed from combinations of two-type (antidown-type and antiup-type) and three-color (2R, 2B, and 2G) superquarks. They have electric charge to be 0, $-e$, $+e$, and $-2e$.

In the Case-I formed normal positively charged baryons P^{+}, there is a stable particle, which is proton, composed of three first-generation quarks (uud) with colors (RBG). In the Case-I formed normal electrically neutral particles P^{0}, there is, when bound in nuclei, another stable particle, which is neutron, composed of three first-generation quarks (udd) with colors (RBG). A free neutron decays into a proton by emitting an electron and an electron-type antineutrino with lifetime about 880 seconds. All other normal baryons quickly decay via various routes towards the most stable one, proton, that leads to the present universe to be dominated by protons for the matter. Under the two-flavor multi-excitation quark model, a proton is composed of $\left(u_0 u_1 d_0\right)$ and a neutron is composed of $\left(u_0 d_0 d_1\right)$.

6. Candidates of Dark Matter Particles

We propose that, within the Case-I formed electrically neutral nonaquarks, S^{0}, a stable particle exists, named as superon, denoted by s^{0}, and considered as a candidate of dark matter particles. A superon consists of three superquarks, each formed from one first-generation quark and two first-generation antiquarks. In quark notation, $s^{0} = \left(uud\overline{ddd}\overline{uuu}\right)$, which can be arranged according to its three superquarks as $s^{0} = \left(u\bar{u}\bar{d}, u\bar{u}\bar{d}, d\bar{d}\bar{u}\right)$. Under the two-flavor multi-excitation model of quarks, this becomes $s^{0} = \left(u_0 u_1 d_0 \bar{d}_0 \bar{d}_0 \bar{d}_0 \bar{u}_0 \bar{u}_0 \bar{u}_0\right)$, grouped as $s^{0} = \left(u_0 \bar{d}_0 \bar{u}_0, u_1 \bar{d}_0 \bar{u}_0, d_0 \bar{d}_0 \bar{u}_0\right)$. As the lowest-energy neutral nonaquark state, it is stable against decay. In contrast, the other three charged nonaquarks are unstable and rapidly transmute into the neutral configuration through processes such as beta decay, positron emission (or electron capture), and double beta decay. The lowest energy states of the three charged nonaquarks have energies all higher than the neutral superon and hence are unstable and decay. Their three quarks are those of forming the unstable neutron and sigma particles. The decay modes of the excited quarks are like those of the excited quarks in normal baryons.

Drawing an analogy with protons—where three quarks with total mass of ~9.2 MeV combines to form a 931 MeV particle (about 100 times increase in mass) due to strong binding—we estimate that a superon, formed via two-level color-charge binding, has a significantly larger mass. Its mass likely falls in the GeV to hundreds-of-GeV range, comparable to weakly interacting massive particles (WIMPs). If all antiquarks are consumed in forming nonaquarks, the resulting particle populations naturally explain the dominance of dark matter over ordinary matter. Matching cosmological observations (~27% dark matter vs. ~5% ordinary matter) suggests a superon mass of about 5 GeV, consistent with light WIMP candidates. Similarly, scaling from quark confinement sizes, such that the color charge binding of three-first generation quarks with radii each around 10^{-18} m to form a proton with radius about 10^{-15} m (about 10^3 times increase in size), suggests a superon has a radius between 10^{-15} m and 10^{-12} m—larger than a nucleus but still far smaller than an atom. Its total mass arises from the combined masses of three superquarks plus their binding energy. Its spin nature leaves for future study.

Because the superon is neutral in both electric and color charges and its constituent quarks and antiquarks are deeply confined within a two-level color-charge or strong force binding structure, its interactions with ordinary matter such as a charged particle are extremely weak but depends on how the particle strikes on the superon. Gravitational interaction dominates unless a particle directly penetrates its structure. Shallow interactions (*i.e.*, striking into the superon but not yet penetrating the inside superquarks) lead to electromagnetic scattering (*i.e.*, Coulomb scattering), while a deeper penetration into a superquark inside the superon may excite the system and produce leptonic emissions such as beta decays.

Nonaquarks are not antimatter because they consist of three superquarks, which carry combined color charges (2R, 2B, 2G) rather than anticolors. They represent a new class of particles not previously explored. High-energy heavy-ion collisions, such as those in particle accelerators or heavy ion colliders, could potentially create these states of particles in quark-gluon plasmas with enough long lifetimes. Charged nonaquarks might be detected through their decay (such as beta decays) signatures into neutral superons.

This framework offers a possible explanation for the observed imbalance between matter and antimatter. Instead of antiquarks forming antimatter, they are incorporated—together with part of the quark population—into nonaquarks that behave as dark matter. In this picture, half of the quarks form ordinary matter, while the remaining quarks and all antiquarks contribute to dark matter.

The underlying mechanism is a two-level color-charge binding. At the first level, gluon-mediated strong interactions bind a quark with two antiquarks into a superquark. At the second level, an enhanced strong interaction binds three superquarks into a nonaquark. This layered structure resembles nuclear formation (quarks → nucleons → nuclei) and molecular formation (nuclei → atoms → molecules), where multi-level binding enhances stability. Consequently, nonaquarks are expected to be more stable than single-level exotic states such as tetraquarks or pentaquarks, which typically decay rapidly into simpler hadrons.

In the early universe, numerous quark-antiquark combinations were possible, but only color-neutral configurations persisted. These include mesons, baryons, exotic hadrons, and the proposed nonaquarks. Most mesons and exotic baryons are unstable and decay quickly, while antibaryons annihilate with baryons. By the end of the hadron epoch (≈ 1 second after the Big Bang), only stable particles remain: protons and neutrons for ordinary matter, superons for superhadronic dark matter, and stable leptons such as electrons and neutrinos.

This model reinterprets quark-antiquark organization in the early universe. Rather than producing equal amounts of matter and antimatter, it partitions quarks and antiquarks into two sectors: ordinary baryonic matter and stable, weakly interacting nonaquark states. This provides a unified explanation for both the apparent absence of antimatter and the origin of dark matter in the universe.

7. Conclusion

We have investigated how particles could form in the early universe following the quark epoch and identified a mechanism for generating dark matter candidates known as nonaquarks. These particles arise from configurations in which quarks combine with twice as many antiquarks, producing a bound state of three quarks and six antiquarks through a two-level color-charge interaction. Among the four possible types, the electrically neutral configuration composed of first-generation (up and down) or the lowest state quarks and antiquarks is stable and thus a strong candidate for dark matter particles, weakly interacting massive particles (WIMPs). This formation pathway, involving an excess of antiquarks, offers a potential explanation for both the observed baryon asymmetry and the origin of dark matter.

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Conflicts of Interest

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

References

[1] Khlopov, M.Y., Rubin, S.G. and Sakharov, A.S. (2000) Possible Origin of Antimatter Regions in the Baryon Dominated Universe. *Physical Review D*, **62**, Article 083505. https://doi.org/10.1103/physrevd.62.083505

[2] Dodelson, S. and Widrow, L.M. (1990) Baryogenesis in a Baryon-Symmetric Universe. *Physical Review D*, **42**, 326-342. https://doi.org/10.1103/physrevd.42.326

[3] Arkani-Hamed, N., Finkbeiner, D.P., Slatyer, T.R. and Weiner, N. (2009) A Theory of Dark Matter. *Physical Review D*, **79**, Article 015014. https://doi.org/10.1103/physrevd.79.015014

[4] Weinberg, S. (2001) Cosmology. Oxford University Press.

[5] Kolb, W.W., and Turner, M.S. (1990) The Early Universe. Addison-Wesley.

[6] McLerran, L. (1986) The Physics of the Quark-Gluon Plasma. *Reviews of Modern Physics*, **58**, 1021-1064. https://doi.org/10.1103/revmodphys.58.1021

[7] Feng, J.L. (2010) Dark Matter Candidates from Particle Physics and Methods of Detection. *Annual Review of Astronomy and Astrophysics*, **48**, 495-545. https://doi.org/10.1146/annurev-astro-082708-101659

[8] Azizi, K., Agaev, S.S. and Sundu, H. (2020) The Scalar Hexaquark *uuddss*: A Candidate to Dark Matter? *Journal of Physics G*: *Nuclear and Particle Physics*, **47**, Article 095001. https://doi.org/10.1088/1361-6471/ab9a0e

[9] Zhang, T.X. (2026) Nonaquarks: A Possible Candidate of Dark Matter Particles. APS Global Physics Summit, Denver, Colorado, Poster Presentation Abstract 284.

[10] Zhang, T.X. (2023) New Insights into the Weak Interaction and Quark Model. *Quark Matter* 2023 *Conference*, Houston, 3-9 September 2023. Poster Presentation, Abstract #88. https://indi.to/W77Vf

[11] Zhang, T. (2025) Two-Flavor Multi-Excitation Model of Quarks. *Journal of Modern Physics*, **16**, 1243-1268. https://doi.org/10.4236/jmp.2025.169065

[12] Zhang, T.X. (2025) New Four-Element Theory of Nature. *Progress in Physics*, **21**, 137-146. https://www.progress-in-physics.com/2025/PP-71-06.PDF

[13] Zhang, T.X. (2025) Mysteries of Antimatter and Dark Matter: Formation of Nonaquarks in the Early Universe. *National Society of Black Physicists* 2025 *Meeting*, San Jose, 19-23 November 2025. Oral Presentation, Nuclear and Particle Physics Session II.

[14] Zhang, T.X. (2026) Insights into Quick Production and Slow Decay of Strange Particles from the New Quantum World of Quarks. *The* 22*nd International Conference on Strangeness in Quark Matter*, Los Angels, 22-27 March 2026. Poster Presentation, Abstract #86.

[15] Wilczek, F. (1982) Quantum Chromodynamics: The Modern Theory of the Strong Interaction. *Annual Review of Nuclear and Particle Science*, **32**, 177-209. https://doi.org/10.1146/annurev.ns.32.120182.001141

[16] Greiner, W., Schramm, S. and Stein E. (2007) Quantum Chromodynamic. 3rd Edition, Springer

[17] Griffiths, D. (2008) Introduction to Elementary Particles. Wiley.

[18] Bander, M. (1981) Theories of Quark Confinement. *Physics Reports*, **75**, 205-286. https://doi.org/10.1016/0370-1573(81)90026-0