The Quark Dirac Sea and the Contracted Universe

Cooperate to Produce the Big Bang with the Quark Energy

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Abstract

The Big Bang theory cannot and does not provide any explanation for the primordial hot and dense initial condition. In order to give an explanation for the cause of the Big Bang,
this paper expands the original Dirac sea (which includes only electrons) to the quark Dirac sea (QDS) including quarks (u and d) for producing the Big Bang with quark energy.

The QDS is composed of “relatively infinite” u-quarks and d-quarks as well as electrons with negative energy in the vacuum. A huge number of domains with sizes much smaller than $10^{-18}$ m of the body-central cubic quark lattice with a lattice constant “a” = Planck length $(1.62 \times 10^{-35}$ m) are distributed randomly over the QDS. The QDS is a homogeneous, isotropic, equivalent “continuous” and “empty” (no net electric charge, no net color charge, no gravitational force field since the gravitational potential is the same at any physical point in the QDS) perfect vacuum model.

The gravity of the universe pulls on the quarks inside the QDS. The pulling force becomes larger and larger as the universe shrinks and shrinks. Once the pulling force is larger than the binding force on the quarks by the whole QDS, a huge number of quarks and antiquarks will be excited out from the QDS. This is a necessary and sufficient condition for the Big Bang.

The huge number of excited quark-antiquark pairs annihilate back to the QDS and release a huge amount of energy; the huge number of excited quarks (or antiquarks) combine into baryons (or antibaryons) and release a huge amount of energy; the combined baryon-antibaryon pairs annihilate back to the QDS and release a huge amount of energy also. Together, these huge quark energies make the Big Bang at its finite size with radius $R = 2.24 \times 10^4$ m.

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Key words: Big Bang, quark Dirac sea, quark energy, contracted universe, phenomenology.
1 Introduction

The Big Bang [1] is the cosmological model of the universe that is best supported by all lines of scientific evidence and observation [2] [3]. The essential idea is that the universe has expanded from a primordial hot and dense initial condition at some finite time in the past and continues to expand to this day.

“Without any evidence associated with the earliest instant of the expansion, the Big Bang theory cannot and does not provide any explanation for such an initial condition; rather, it describes and explains the general evolution of the universe since that instant.” (Big Bang-Wikipedia, the free encyclopedia). This is a weak point of the Big Bang theory. Anyway we should give a reasonable explanation for the initial condition (the origin) of the Big Bang. This paper will spell out where the energy of the Big Bang comes from.

All known energies, however, are not large enough to make such a special anomalous Big Bang. Nuclear fusion energy is the highest energy humans have ever known, it still cannot make the Big Bang. For example, a large quantity of hydrogen has been fusing to helium in our closest star, the Sun, for billions of years. Although these nuclear fusion reactions produce large quantities of energy, it is not enough to overcome the gravitation of the Sun. Thus the nuclear fusion energy is not enough to make the Big Bang of the universe. This paper suggests that there is one and only one kind of energy, the quark energy, which can make the Big Bang.

In order to improve the Big Bang theory, this paper tries to provide a mechanism to produce the Big Bang naturally using the quark energy. Where does the quark energy comes from? There is only the vacuum which might provide the quark energy and there is nothing else.

Inside the current vacuum model (the Dirac sea model), however, there is only electrons that
cannot provide the quark energy. Thus, we have to expand the Dirac sea model from only including
electrons to including quarks (u and d) and electrons for providing quark energy from the vacuum.

The Dirac sea [4] is a theoretical model of the vacuum as an infinite sea of particles possessing
negative energy. It was first postulated by the British physicist Paul Dirac in 1930 to explain
the anomalous negative energy quantum states predicted by the Dirac equation for relativistic
electrons. At that time quarks were unknown, so the Dirac sea only included electrons. Similarly,
the quarks [5] are fermions with spin = \( \frac{1}{2} \) and obey the Dirac equation as well as have negative
energy state solutions. Therefore, from the original Dirac sea, we extend the model to a new Dirac
sea (the quark Dirac sea) which includes the quarks. Although there are six flavored quarks, only
two kinds of quarks (u and d) can compose stable baryons. Since the vacuum is absolutely stable,
as a vacuum model, the new Dirac sea, cannot include other quarks (s, c, b and t) which cannot
compose any stable baryon. In fact the numbers of these quarks (s, c, b and t) are too small and
the lifetimes of these quarks are too short to compose a stable vacuum. Thus we omit them. In
order to avoid confusion, we call the new Dirac sea, including u-quarks and d-quarks as well as
electrons, the quark Dirac sea (QDS); we call the Dirac sea, including only electrons, the original
Dirac sea.

At the same time, we have to incorporate the advantages of the current Big Bang models. There are many Big Bang models now. They all have some advantages which we shall incorporate.
Such as:

The inflationary model is to set up the initial conditions for the standard model and explain the
large-scale uniformity of the universe [?]. These arouse us. This paper will provides a mechanism
to produce a huge energy for the Big Bang and to produce a physical firm foundation for the
uniformity of the universe.
The oscillatory Big Bang model investigated by Einstein in 1930 and critiqued by Richard Tolman [6] in 1934, in which the universe undergoes a series of oscillations, each beginning with a big bang and ending with a big crunch. The big crunch prepares for the next Big Bang. We shall incorporate this.

The above theory has been revived in cosmology as the cyclic model [7] and the Big Bounce [8] [9], ...

The “primeval atom” model, Lemaitre (1931) suggested that the universe contracted backward in time, and would continue to do so until it could contract no further, bringing all the mass of the universe into a single point, a “primeval atom”, before the point time and space did not exist [?]. Hawking points suggested that before the Big Bang, the universe contracted to a singularity with infinite density and infinite temperature [10]. Although we do not believe the “primeval atom” really exist, we think that before the Big Bang, the universe really contract to very small size. We will incorporate this. For example, there is the oscillatory Big Bang model investigated by Einstein in 1930 and critiqued by Richard Tolman [6] in 1934, in which the universe undergoes a series of oscillations, each beginning with a big bang and ending with a big crunch. The theory has been revived in cosmology as the cyclic model [7] and the Big Bounce [8] [9], .... Using general relativity, Hawking points out [10]: before the Big Bang, the universe contracted to a singularity with infinite density and infinite temperature (since quantum effects, the singularity can not be reached). Although the above models are not completely the same, they have a common characteristic in that the universe undergoes a contraction process before the Big Bang. This is the common characteristic of the Big Bang models, we shall incorporate this into our mechanism.

We will briefly show how the contracted universe and the quark Dirac sea can cooperate to produce the Big Bang with quark energy now. According to the common characteristic of the
above current Big Bang models, the universe undergoes a contraction before the Big Bang. Thus, the universe with a huge mass is compressed by the gravity of the universe before the Big Bang. At the same time, the universe is pulling on the quarks inside the quark Dirac sea (in the vacuum) with gravitational force. As the size of the universe becomes smaller and smaller, the pulling force becomes larger and larger. Thus eventually a critical point will be reached: the universe’s gravitational pulling force (on the quarks) overcomes the quark Dirac sea binding force (on the same quarks), and the quarks (and their antiquarks) will be excited out from the quark Dirac sea (the vacuum) negative energy state. Like electrons inside the Dirac sea (the vacuum) negative energy state are no observable electric charges and masses, but once they are excited out from the negative state inside the Dirac sea, they obtain their observable electric charges and masses. Similarly, although the quarks and antiquarks are no observable electric charges, color charges and masses, once the quarks and antiquarks are excited from the quark Dirac sea will show their electric charges, color charges and masses. Thus the exciting process increases the mass of the universe and the pulling force (from the excited quarks and antiquarks) as well as decreases the binding force of the quark Dirac sea. So that, more and more quarks (and their antiquarks) are pulled out from the quark Dirac sea. At the same time, the huge number of excited quarks (and their antiquarks) will combine into baryons (antibaryons) and release a huge amount of energy to produce the Big Bang. Three quarks combine into a baryons to release much larger energy than a nuclear fusion from the quark confinement fact. In addition, the baryon-antibaryon pairs annihilate and release even more energy for the Big Bang. Once the universe expands large enough, and the universe’s pulling force becomes small enough (smaller than binding force of the QDS), it cannot pull the quarks (antiquarks) out any more. The universe has already pulled out a huge amount of quarks and their antiquarks from the quark Dirac sea. These quarks and antiquarks
well produce a huge amount of quark energy to produce the Big Bang. The details will be shown in the following sections.

2 The Original Dirac Sea–The Earliest Model of the Vacuum

The earliest theoretical model of the vacuum is the Dirac sea as an infinite sea of electrons possessing negative energy. It was invented by the British physicist Paul Dirac in 1930 to explain the anomalous negative-energy quantum states predicted by the Dirac equation for relativistic electrons [4]. The positron, the antimatter counterpart of the electron, was originally conceived as a hole in the Dirac sea, well before its experimental discovery in 1932.

2.1 The advantages of the original Dirac sea model

The original Dirac sea theory makes three great predictions:

1. It predicts an antiparticle—a hole of the negative energy particle in the Dirac sea.

2. In the original Dirac sea theory, the particle and its antiparticle are not absolutely symmetric. The particles have positive energy and outside the original Dirac sea; the antiparticles are the holes of the original Dirac sea. Although the holes have an equivalent electric charge and mass of the antiparticles, they are temporary particles. Once they depart from the original Dirac sea, they will disappear. Thus we can understand why there are only the particle occupying the current universe.

3. It predicts that the empty space (the vacuum) is not really empty. It is fully filled by the electrons with negative energy. Thus it can produce electron-antielectron pairs (an electron
is excited from the original Dirac sea and leaves an electron hole in the original Dirac sea) and it can accept electron-antielectron pair annihilations (the electrons fill back into the holes). The original Dirac sea provides a physical foundation for electron-antielectron pair production and annihilation. If the original Dirac sea is not in the vacuum, it will be difficult to understand why electron-antielectron pairs can be produced from the vacuum (“the empty space”).

2.2 The weaknesses of the original Dirac sea theory

Despite its success, at the same time, there are some weaknesses in the original Dirac sea theory:

1. The existence of the original Dirac sea implies infinite negative electric charges filling all of space. In order to make any sense out of this, one must assume that the “bare vacuum” must have an infinite positive charge which is exactly canceled by the original Dirac sea. We need an electrically neutral Dirac sea. Thus we have to add particles with positive electric charges (such as the u-quarks with $Q = \frac{2}{3}$) into the sea to cancel the negative electric charges of the electrons.

2. The existence of the original Dirac sea implies infinite negative electric charges filling all of space. Because of the repulsive forces of the infinite negative electric charges, the original Dirac sea (vacuum) will be unstable. We need a stable structure of the Dirac sea. According to the solid state physics, the most stable structures of many body systems are the lattices. Maybe an ideal Dirac sea will have a lattice structure also.

3. Pauli exclusion does not definitively mean that a filled Dirac sea can not accept more electrons. Since, as Hilbert elucidated, a sea of infinite extent can accept new particles even if it is filled. We might need another condition to ensure that the Dirac sea can not accept more “electrons”. What is the condition? Maybe a new model is needed.

4. Although the original Dirac sea theory has successfully explained the electron-antielectron
pair productions (electrons are excited from the original Dirac sea and leave their holes in the
sea) and annihilations (the electrons go back into their holes in the original dirac sea), it cannot
explain the $p-\bar{p}$ pair and $n-\bar{n}$ pair productions and annihilations since there is not any quark in
the original Dirac sea. These pair productions (from the vacuum) and annihilates (back to the
vacuum) are supported by a lot of experimental facts. As a model of vacuum, it has to give a
reasonable explanation. Thus it is necessary to have $u$-quarks and $d$-quarks inside the Dirac sea.

The above weaknesses must be corrected. Thus we need a new model of the vacuum to correct
the weaknesses, and to incorporate and develop the advantages of the original Dirac sea theory.

3 The Quark Dirac Sea Model (QDS) of the Vacuum

As mentioned above, the earliest model of the vacuum, the original Dirac sea model, has three
advantages. We must adopt and develop these advantages. At the same time, there are some
weaknesses in the original Dirac sea model. We have to correct the weaknesses using a new
model. Since the birth of the original Dirac sea model, more than seventy-five years have passed;
during this period physics and astronomy have made great progress. The new achievements of
physics, especial the quark model and the solid state physics, provide good conditions for further
improvement and development of the original Dirac sea model.

3.1 The fundamental postulates of the quark Dirac sea model

The quark model is one of the most important new achievements [5]. There are six flavored quarks
in the model: $u$-quarks, $d$-quarks, $s$-quarks, $c$-quarks, $b$-quarks and $t$-quarks. They are fermions
with spin $s = \frac{1}{2}$. They all obey the Dirac equation. Like electrons, there are positive energy state
solutions and negative energy state solutions of the Dirac equation for the u-quarks, the d-quarks, ..., in real world. For the electrons there is an infinite original Dirac sea of electrons with negative energy in the vacuum. Similarly, there are an u-quark Dirac sea of the u-quarks with negative energy, a d-quark Dirac sea of the d-quarks with negative energy, ..., in the vacuum also. The numbers of the s-quarks, the c-quarks, the b-quarksm and the t-quarks are much smaller than the numbers of the u-quarks and the d-quarks. And only u-quarks and d-quarks can compose stable matter. We do not believe that the unstable quarks (s, c, b and t) can compose the absolutely stable vacuum. As an approximation, we assume that the u-quarks and the d-quarks and the electrons mainly compose the physical vacuum.

Although there are photons between the electrons, they are completely neglected in the original Dirac sea model and various solid state lattice models. Similarly, although there are gluons between the quarks, in order to simplify, they will be phenomenologically neglected in the quark Dirac sea model.

In order to avoid confusion with the mathematical and philosophic term “infinite”, we define a “relatively infinite” system as follows: if a system is beyond the region of electric force and gravitational force as well as human observation, it is “relatively infinitely” far; if the boundary of a system is as far as “relatively infinite”, we call the system as “relatively infinitely” large. In fact, some “relatively infinitely” large systems are finite in mathematics and in philosophy.

In order to make a phenomenological vacuum model, we assume:

Postulate I: There is a “relatively infinite” large quark Dirac sea (QDS) which is completely filled with the negative energy u-quarks and d-quarks as well as electrons inside the vacuum.

According to Dirac sea theory [4], the particles with negative energy are in the vacuum state
and there is not any observable physical effect for these negative energy electrons. Similarly, the negative energy u-quarks and d-quarks are in the vacuum state of the quark Dirac sea, there is not any observable physical effect for these negative energy quarks (u and d) also.

A huge system usually will be divided many parts. For example, a large chunk of ferrous metal is always composed of many very small micro-crystal grains. The “relatively infinite” quark Dirac sea will be divided into a huge number of domains also. The domains have not be discovered by the standard model. Thus we guess that the sizes of the domains are much smaller than the distance scale $10^{-18}$ m of the standard model [11].

**Postulate II:** The quark Dirac sea is fully filled with domains. The domains are completely randomly distributed in sizes and in positions as well as in directions of symmetry axes of the quark lattice in the domains (see Postulate III). The sizes of the domains are much smaller than the distance scalar $10^{-18}$ m of the standard model.

The domains are completely randomly distributed in sizes and in positions as well as in directions of symmetry axis of the domains (see Postulate III). Their sizes are much smaller than the distance scale $10^{-18}$ m of the standard model. Thus, the quark Dirac sea is homogeneous and isotropic as well as “continuous” from the statistics and the opinion of the standard model.

If there is an empty position of u-quark (or d-quark or electron) in any domain, an u-quark (or d-quark or electron) with positive energy will fall down into the position to make the domain completely full.

There are negative energy u-quarks and d-quarks as well as electrons inside a domain. There are strong interactions and electromagnetic interactions among these negative particles. The strong interactions is much larger than the electromagnetic interactions, it determines and holds the structure of the domains. The electrons are much smaller than the quarks and they do not have
strong interactions with the quarks and the electrons. The electrons do not play an important role in the structure of the domains. We only consider u-quarks and d-quarks, while neglecting the electrons. Thus we think temporally there are only the u-quarks and the d-quarks in the domains. The strong pulling forces drive the u-quarks and the d-quarks to form the densest quark Dirac sea in the vacuums.

From the experimental mass (938 Mev) of proton (uud) is close to the mass (940 Mev) of neutron (udd), we can estimate that the mass of u is close to the mass of d and the radius $r_u$ of the u-quarks is close to the radius $r_d$ of the d-quarks:

$$r_u \approx r_d.$$  \hspace{1cm} (1)

If using the current quark masses: $m_u = 2.55$ Mev and $m_d = 5.04$ Mev \cite{12}, and assume their densities are the same ($\rho_u = \rho_d$), the volume $V_u = \frac{m_u}{\rho_u}$ and the volume $V_d = \frac{m_d}{\rho_d}$. Using the Formula $V = \frac{4\pi r^3}{3} \rightarrow r = \sqrt[3]{\frac{3V}{4\pi}}$, we have

$$\frac{r_u}{r_d} = \sqrt[3]{\frac{m_u}{\rho_u}} \div \sqrt[3]{\frac{m_d}{\rho_d}} = 0.797$$  \hspace{1cm} (2)

From both Formulae (1) and (3), we get

$$1 \geq \frac{r_u}{r_d} \geq 0.73,$$  \hspace{1cm} (3)

According to the crystal structure theory \cite{13}, for two kinds of different particles (such as u and d), if $1 \geq \frac{r_u}{r_d} \geq 0.73$, the densest structure of the u-quarks and the d-quarks is a body-central cubic quark lattice. Note that inside the quark lattice, the eight nearest neighbors of any u-quark are all d-quarks and the eight nearest neighbors of any d-quark are all u-quarks.

The u-quarks have electric charge $Q_u = +\frac{2}{3}$ and the d-quarks have electric charge $Q_d = -\frac{1}{3}$. Coulomb’s repulsive forces separate the u-quarks with the same charges and the d-quarks with the
same charges; while Coulomb’s attractive forces pull the u-quarks and the d-quarks to approach each other since they have positive and negative charges. So that the u-quarks and the d-quarks form a quark lattice that the nearest neighbors of any u-quark are all d-quarks and the nearest neighbors of any d-quark are all u-quarks. The body-central cubic lattice is just this kind of lattice.

Thus, the strong interactions and electromagnetic interactions of the u-quarks and the d-quarks cooperate to form a super strong body-central cubic quark lattice as shown in Figure 1 (a).

If we consider the u-quarks in the quark Dirac sea only, the u-quarks form a simple cubic u-quark lattice (see Figure 1 (b)). If only consider the d-quarks inside the quark lattice, they form a simple cubic d-quark lattice also (see Figure 1 (c)).

Figure 1. The body-central cubic quark lattice. Figure 1 (a) shows the body-central cubic quark (u and d) lattice. The u-quarks are at the corners of the conventional cells, the d-quarks are at the centers of the conventional cells. Figure 1 (b) shows the simple cubic u-quark lattice. Figure 1 (c) shows the simple cubic d-quark lattice.
In the lattice, a kind of quarks (such as d-quarks) are at the centers of the conventional cells and the other kind of quarks (u-quarks) are at the corners of the conventional cells. The conventional cell and the primitive cell are shown in Figure 2. In Figure 2 (b), the d-quark (at the center) and the u-quarks (at the corners). The center quarks and the corner quarks can exchange with each other. This depends on your chosen coordinates (the origin point on which quark).
Figure 2. The primitive cell and the conventional cell of the body-central cubic quark lattice. Figure 2 (a) shows a primitive cell. The primitive cell shown is a rhombohedron of edge $\sqrt{3}a/2$ and the angle between adjacent edges is $109^\circ28'$. Figure 2 (b) shows a conventional cell. A d-quark at the center and eight u-quarks are at the eight corners of the conventional cell.

There is a piece of body central cubic quark (u and d) lattice in a domain of the quark Dirac sea. The sizes of the domains are much smaller than the distance scale $10^{-18}$ m of the standard model since the standard model has not found the domains and the standard model works at distance scalar $\geq 10^{-18}$ m [11]. The periodic constant “a” is very important. First, it has to be much smaller than the size of the domains (the sizes of domains are much smaller than $10^{-18}$m), i.e. “a” $\ll 10^{-18}$m. Second, loop quantum gravity point out that the space is a mesh of tiny “atoms” (spheres). The diameter of the atoms is the Planck length [9]. Thus we take the lattice constant as the Planck length ‘a’ = $1.62 \times 10^{-35}$m [14].

Postulate III: Each domain is a piece of body-central cubic quark lattice. In the lattice, one kind of quarks (such as d) are at the centers, the other kind of quarks
(such as u) are at the corners, and the electrons are freely moving inside the lattice. The quark lattice constant is the Planck length “a” = 1.62×10^{-35} m.

The physical vacuum has no net electric charge. Thus the number of u-quarks ($N_u$) equals the number of the d-quarks ($N_d$) equals 3 times the number of the electrons ($N_e$) in the perfect quark Dirac sea domains ($3N_u = 3N_d = N_e$) to ensure the total electric charge of the quark Dirac sea equals zero in each domain. Each primitive cell of the body-central cubic lattice has two quarks [13], the u-quark with $Q_u = +\frac{2}{3}$ and the d-quark with $Q_d = -\frac{1}{3}$, it has total $Q = +\frac{1}{3}$. Each of the three primitive cells add an electron with $Q_e = -1$. Thus the three primitive cells have electric charge $Q = 0$. For any physical point, we mean that a small ball with radius $r = 10^{-18}$ m and its center at the point, and the total electric charge $Q_{Point} = 0$.

**Postulate IV:** The number of the u-quarks equals the number of the d-quarks equals three times the number of the electrons in each domain of the quark Dirac sea. Each primitive cell has two quarks (u and d), nearest three primitive cells contain an electron.

The physical vacuum has no net color charge. Thus, the number of u-quarks with red color equals the number of u-quarks with green color equals the number of u-quarks with blue color, and the number of d-quarks with red color equals the number of d-quarks with green color equals the number of d-quarks with blue color, to ensure the total net color charges of the quark Dirac sea domain equals zero. Each primitive cell has different colors for each quark, three nearest neighboring primitive cells have white color for the quark-u and the quark-d.

**Postulate V:** For the u-quarks and the d-quarks there are the same numbers of red quarks and green quarks as well as blue quarks in each domain of the quark Dirac sea. Three nearest neighboring primitive cells have white color (or colorless).
The quark Dirac sea has “relatively infinite” number of u-quarks and d-quarks as well as electrons in the vacuum. Since these particles all have finite masses, the quark Dirac sea has “relatively infinite” mass. Because the quark Dirac sea is homogenous and isotropic, the gravitational potential is homogenous and isotropic (a constant) in the vacuum. The gravitational potential is a constant anywhere yields that the gravitational field equals zero at anywhere in the quark Dirac sea.

Postulate VI: The quark Dirac sea provides a constant gravitational potential \( V_{QD} \) (maybe “relatively infinite”) at any point. We select the potential as the energy zero point \( V_{QD} = 0 \). The constant gravitational potential leads to the gravitational field \( F_G \) equals zero \( (F_G = 0) \).

The quark Dirac sea is a homogeneous, isotropic, “continuous” and “empty” (no electric charge, no color charge, no effective “mass” (no gravitational potential and no gravitational field) at any physical point in the quark Dirac sea) perfect vacuum model.

3.2 The quark Dirac sea model (QDS) corrects the three weaknesses of the original Dirac sea model

1. The original Dirac sea model implies an infinite negative electric charges filling all of the space. This is not in agreement with the fact that the vacuum is without any electric charge. The new model (QDS) has no electric charge and color charge at any physical point of the quark Dirac sea. Thus it is in agreement with the empty vacuum space.

2. The original Dirac sea is unstable since there are the forces of repulsion between the negative electric charges of the electrons in the sea. For the quark Dirac sea model, however, there are strong
pulling forces between the quarks (no strong repulsion). In the QDS, for any u-quark with \( Q = \frac{2}{3} \), there are always eight nearest neighbor d-quarks with \( Q = -\frac{1}{3} \); for any d-quark with \( Q = -\frac{1}{3} \), there are always eight neighbors u-quarks. Thus the pulling electric forces between the quarks dominate over the repulsions. The quark Dirac sea is a super-stable structure, it is real like the vacuum space that has never been changed.

3. The original Dirac sea might be, as Hilbert elucidated (Hilbert’s paradox of the Grand Hotel), a sea of infinite extent that can accept new particles even if it is filled. The quark Dirac sea is composed of domains. Any domain is fully occupied by the finite u-quarks and the finite d-quarks as well as finite electrons, and there is not any empty position from Postulate II. According to Pauli exclusion, there is zero possibility to accept any particle in any domain. The possibility of any domain accepting any particle is zero. Since infinite zero sum together is still zero \( \sum 0 = 0 \), the ideal quark Dirac sea cannot accept any additional particles.

3.3 The quark Dirac sea (QDS) incorporates and develops the advantages of the original Dirac Sea

The quark Dirac sea model not only corrects all three weaknesses of the original Dirac sea, but also incorporates and develops all advantages of the original Dirac sea:

1. The quark Dirac sea predicts the antiparticles, these are the holes in the quark Dirac sea: An electron hole of the quark Dirac sea is an antielectron, an u-quark hole of the quark Dirac sea is an anti-u-quark and a d-quark hole of the quark Dirac sea is an anti-d-quark. The quark Dirac sea not only provides a natural explanation of the antielectron, but also produces a natural explanation of anti-u-quarks and anti-d-quarks.
2. The quark Dirac sea predicts that the particle-antiparticle pairs usually are created simultaneously or annihilate with each other. A quark (u or d) is excited from the quark Dirac sea and an antiquark ($\bar{u}$ or $\bar{d}$) left in the quark Dirac sea at the same time. This is a quark-antiquark pair production. On the other hand, when a quark (u or d) falls into its hole (u-hole or d-hole) in the quark Dirac sea, this is a quark-antiquark pair annihilation. Similarly, if three quarks (uud or udd inside the QDS) are hit by the same force at the same time with the similar strength, they may be excited together from the quark Dirac sea, a three fold hole ($\overline{uud}$ or $\overline{udd}$) will be left in the quark Dirac sea, this is a baryon-antibaryon production. A baryon (uud or udd) falls back its three fold hole ($\overline{uud}$ or $\overline{udd}$) this is a baryon-antibaryon pair annihilation. The quark Dirac sea not only can explain the quark pairs ($u\bar{u}$ or $d\bar{d}$) production and annihilation, but also can explain the baryon-antibaryon ($uud\bar{uud}$, or $udd\bar{udd}$) pair production and annihilation.

3. The quark Dirac sea predicts that the “empty” space (the vacuum) is not really empty. The “empty” space is fully occupied by u-quarks and d-quarks as well as electrons with negative energy. These quarks and electrons form a super-strong homogeneous and isotropic structure, and have no electric charge, no color charge and no effective “mass” (gravitational potential $V_{QD} = 0$ and field $F_G = 0, F_G = 0$ from Postulate VI) at any physical point “empty” vacuum. This provides a perfect super-stable stage for various physical bodies, particles, stars and fields.

3.4 The quark Dirac sea (QDS) is a perfect vacuum model

According to the original Dirac sea theory [4], the infinite electrons with negative energy make the vacuum background without any observable effect. Similarly, the negative energy u-quarks and d-quarks as well as electrons in the quark Dirac sea form a perfect physical vacuum without any observable effect also. This is true due to four very strong reasons:
First, from Postulate II, the domains are completely randomly distributed in positions and in directions of symmetry axis of the body-central quark lattice in the domains. Thus, the quark Dirac Sea is homogeneous and isotropic from statistics. The domain sizes are much smaller than the distance scale $10^{-18}$ m of the standard model. The lattice constant “a” = $1.62 \times 10^{-35}$ m is much smaller than the distance scale $10^{-18}$ m of the standard model. Therefore the standard model looks at the quark Dirac sea as a homogeneous and isotropic as well as “continuous” space.

Second, there are no electric charge and no color charge as well as no effective “mass” (no gravitational potential and field from Postulate VI) at any physical point (a ball with radius = $10^{-18}$ m) inside the QDS. Thus the quark Dirac sea appears as an empty space.

Third, the quark Dirac Sea is a super-strong structure (from Formula (29) a quark is bound by $-4.03 \times 10^9$ J energy). All known phenomena cannot change the quark Dirac Sea since their energies are too small. For example, the most highest energy phenomena, nuclei fusions, only have energy about $10$ Mev = $10^{-12}$ J $\ll 4.03 \times 10^9$ J. Thus the quark Dirac sea seems to be an unchangeable station of all particles and physical bodies as well as stars . . . . It plays the same role as the vacuum.

Fourth, when a particle is moving in “empty” space, in fact, it is moving in the quark Dirac sea since the space is fully filled with the quark Dirac sea. The particle, in fact, is really moving in the periodic field of the QDS. According to quantum mechanics [16], an ideal lattice does not scatter the particle moving inside the lattice. If the Hamiltonian H of the particle moving in the lattice is independent from time, the states of the particle are stationary. For such a state, the expectative value of any physical quantity which does not depend on time explicitly is constant. Thus a particle is moving in an ideal periodic field of the quark Dirac sea, the ideal periodic field makes the Hamiltonian to be independent from time. Hence the states of the particle are
stationary. So that, the particle looks like to be moving in the vacuum.

The four reasons show that the quark Dirac sea is a homogeneous, isotropic, “continuous” and “empty” space. The particles are moving in the quark Dirac sea as if they are moving in a stable and non-scattering space. Therefore the negative energy particle in the quark Dirac sea do not have any observable effect in the usual phenomena. The quark Dirac sea, however, will play a critical role in the Big Bang of the universe as shown in the following sections.

4 A Huge Number of Quarks and Antiquarks are Pulled Out from the Quark Dirac Sea by the Gravity of the Contracted Universe

It is a necessary and sufficient condition for the Big Bang that the contracted universe pulls a huge number of quarks and antiquarks from the quark Dirac sea. First, we find the pulling energy of a quark inside the quark Dirac sea by the contracted universe.

4.1 The gravitational pulling energy of a quark in the QDS by the contracted universe

According to the above (Introduction), a common characteristic of the current Big Bang models (the oscillation, the cyclic model and the Big Bounce, . . ., etc) is that the universe undergoes a series of cycles, each beginning with a Big Bang and ending with a big contraction, before (or after) a Big Bang, the universe will contract to a small size. We assume that the universe has shrunk to a small ball with radius R and mass \( M_U \) as well as a density \( \rho(r, \theta, \phi) = \frac{\mathcal{C}}{r} \). The universe’s
contraction is very slow because of the resistances from high density and temperature of matter in the contracted universe. Thus we can use Newtonian mechanics to estimate the pulling energy to a quark inside the QDS by the contracted universe. The pulling energy is defined as the potential energy between the quark (inside the QDS) and the whole contracted universe. A spherical polar coordinate system \((r, \theta, \phi)\) is shown in Figure 3.

![Figure 3](image)

The coordinates' relationships

\[
\begin{align*}
x &= r \sin \theta \cos \phi \\
y &= r \sin \theta \sin \phi \\
z &= r \cos \theta
\end{align*}
\]

The volume element is

\[
d\tau = r^2 \sin \theta dr d\theta d\phi
\]

**Figure 3**

Figure 3. A spherical polar coordinate and a rectangular cartesian coordinates. The relationships of the two coordinates have been shown on Figure 3. The coordinates of the quark are \((r = r_0, \theta = 0, \phi = 0)\) and for any point the coordinates are \((r, \theta, \phi)\).

Using spherical polar coordinates, for any point at \((r, \theta, \phi)\), assuming the mass density of the universe \(\rho(r, \theta, \phi) = \frac{c}{r}\) (\(c\) is a constant), the mass \(M_U\) of the universe is

\[
M_U = \int \int \int \frac{c}{r} r^2 \sin \theta dr d\theta d\phi = 2\pi c R^2, \quad c = \frac{M_U}{2\pi R^2}. \quad (4)
\]

We calculate the gravity pulling energy \(U(r_0, \theta, \phi)\) of a quark inside the quark Dirac sea by the whole contracted universe with mass \(M_U\) and radius \(R\) now. The potential (pulling) energy
u(r, θ, φ) of the quark at the point with coordinates (r = r₀, θ = 0, φ = 0) inside the quark Dirac sea (negative energy state in the vacuum) pulled by a small mass piece ρ(r, θ, φ) of the universe at (r, θ, φ) is

\[ u(r, \theta, \phi) = -\frac{G m q \rho(r)}{d} = -\frac{G m q c}{r \sqrt{r^2 + r_0^2 - 2r_0 r \cos \theta}}, \] (5)

where G = 6.6742 × 10^{-11} m^3 kg^{-1} s^{-2}, d is the distance between any point (r, θ, φ) and the point that the quark occupies (r = r₀, θ = 0, φ = 0); the quark mass \( m_q \) is the average mass of the mass \( m_u \) of the u-quark and the mass \( m_d \) of the d-quark. The \( m_u = 2.55 \) and the \( m_d = 5.04 \) \[12\], thus \( m_q = 3.80 \) Mev.

Using Formula [5], we can calculate the pulling (the gravitational potential) energy \( U(r_0, \theta, \phi) \) of a quark that is pulled by the whole universe as follows:

\[ U(r_0, \theta, \phi) = -\int \int \int u(r, \theta, \phi)r^2 \sin\theta dr d\theta d\phi = -\int \int \int \frac{G m q c}{r \sqrt{r^2 + r_0^2 - 2r_0 r \cos \theta}} r^2 \sin\theta dr d\theta d\phi. \] (6)

Using \( \sin\theta d\theta = d(-\cos\theta) \) and assuming \( -\cos\theta = t \), when \( \theta = 0, t = -1 \) and \( \theta = \pi, t = 1 \). Letting \( r^2 + r_0^2 = b(r) \) and \( 2r_0 r = a(r) \), from [6], we can get

\[ U(r_0, \theta, \phi) = -\int \int \int \frac{G m q c}{\sqrt{a(r)t + b(r)}} r dt dr d\phi. \] (7)

Then using integrating formula \( \int \frac{1}{\sqrt{at+b}} dt = \frac{2}{a} \sqrt{at+b} \), we have

\[ U(r_0, \theta, \phi) = -\int \int \int (G m q c)[\frac{2}{a(r)} \sqrt{a(r)t + b(r)}]_{t=-1}^{t=1} r dt dr d\phi. \] (8)

Putting \( a(r) = 2r_0 r \) and \( b(r) = r^2 + r_0^2 \) in the above formula and making sure when \( t = -1, \sqrt{a(r)t + b(r)} \) to get real values. When \( t = -1, \sqrt{a(r)t + b(r)} = \sqrt{r_0^2 - 2r_0 r + r^2} \). For \( r \geq r_0, \sqrt{a(r)t + b(r)} = (r - r_0); \) for \( r \leq r_0, \sqrt{a(r)t + b(r)} = r_0 - r. \) From [8], we have

\[ U(r_0, \theta, \phi) = -2\pi G m q c \int_{r_0}^{R} \frac{2r}{2r_0 r} [(r + r_0) - (r - r_0)] dr + \int_{0}^{r_0} \frac{2r}{2r_0 r} [(r + r_0) - (r_0 - r)] dr. \] (9)
From (4) \( c = \frac{M_U}{2\pi R} \), putting it in the above expressed formula, we get

\[
U(r_0, \theta, \phi) = -4\pi Gm_q c \left[ \frac{1}{r_0} [r_0(R - r_0) + \frac{(r_0)^2}{2}] - 4\pi Gm_q c (R - \frac{r_0}{2}) \right] = -\frac{2GM_Um_q}{R} (1 - \frac{r_0}{2R}) \tag{10}
\]

Formula (10) shows that the universe’s pulling energy is independent from \( \theta \) and \( \phi \) as well as \( r \). It is only dependent on \( r_0 \). At the center of the universe ball, \( r_0 = 0 \), there is the maximum pulling potential energy (absolute value). From Formula (10), the energy \( U(\text{cent}) \) is

\[
U(\text{cent}) = -\frac{2GM_U m_q}{R}. \tag{11}
\]

Also from Formula (10), the pulling energy \( U(\text{surf}) \) of a quark at the universe surface’s \( (r_0 = R) \) is

\[
U_{\text{surf}} = -\frac{GM_U m_q}{R} \tag{12}
\]

Again from Formula (10), using \( m_b \) of the baryon mass instead the quark mass \( m_q \), we can get the pulling energy \( U(b, U, r_0) \) of a baryon at the \( r_0 \) by the universe and the pulling energy \( U(b, U) \) of a baryon at the center of the universe by the universe:

\[
U(b, U, r_0) = -\frac{2GM_U m_b}{R} (1 - \frac{r_0}{2R}) \quad \text{and} \quad U(b, U) = -\frac{2GM_U m_b}{R}. \tag{13}
\]

### 4.2 The contraction of the universe cannot make the Big Bang

The contraction of the universe indeed can make a high density and a high temperature. For example, when the universe contracts to a small ball with \( R = 2.24 \times 10^4 \text{ m} \) (the critical \( R \) value from (31)), if we know the observable mass \( M_U \) of the current universe we can find the average density \( \bar{\rho} = \frac{3M_U}{4\pi R^3} \) of the universe. The measured mass value of the universe is different using different methods. Such as:

A. K. Velan (1992), \( M_U = 5.86 \times 10^{53} \text{kg} \).
J. Bernstein (1995), $M_U = \text{the number of protons in the visible universe} \times \text{the mass of proton} = 10^{77} \times 1.67 \times 10^{-27} \text{kg} = 1.67 \times 10^{50} \text{kg}$ [18];

H. Kragh (1999), $M_U = \frac{c^3}{2G\hbar} = \frac{c^2}{2G} \times \frac{c}{\hbar} = \frac{c^2}{2G} \times 1.2 \times 10^{26}$ [14] = $0.81 \times 10^{53} \text{kg}$ [19];

D. Harrison (2000), $M_U = \text{a mass of } 10^{80} \text{ nucleons} = 10^{80} \times 1.67 \times 10^{-27} \text{kg} = 1.67 \times 10^{53} \text{kg}$ [20].

From these mass values, we roughly estimate that

$$M_U \approx 1.0 \times 10^{53} \text{kg}. \quad (14)$$

Then the average density $\bar{\rho}$ of the universe with $R = 2.24 \times 10^4$ m is

$$\bar{\rho} = \frac{1.00 \times 10^{53} \text{kg}}{\frac{4\pi}{3} (2.24 \times 10^4 \text{m})^3} = 2.13 \times 10^{39} (\text{kg/m}^3). \quad (15)$$

There is not a formula with which one can deduce the temperature of the contracted universe center. In order to estimate the temperature, we need a phenomenological temperature formula. We assume that the temperature of a celestial sphere center is proportional to its mass and $\frac{1}{R}$ ($R$ is the radius of the sphere):

$$T_s = C_s M_s \frac{1}{R_s}. \quad (16)$$

Using Formula [16] to the earth, we have

$$T_{\text{Earth}} = C_{\text{Earth}} M_{\text{Earth}} \frac{1}{R_{\text{Earth}}}. \quad (17)$$

Using Formula [16] to the Sun, we have

$$T_{\text{Sun}} = C_{\text{Sun}} M_{\text{Sun}} \frac{1}{R_{\text{Sun}}}. \quad (18)$$

From Formulae (18) and (17), we can get

$$T_{\text{Sun}}/T_{\text{Earth}} = C \frac{M_{\text{Sun}}}{M_{\text{Earth}}} \frac{R_{\text{Earth}}}{R_{\text{Sun}}}, \quad (19)$$
where \( C = \frac{C_{Sun}}{C_{Earth}} \). From \((19)\), we get the temperature of the Sun center is
\[
T_{Sun} = C \frac{M_{Sun}}{M_{Earth}} \frac{R_{Earth}}{R_{Sun}} T_{Earth},
\]
(20)
Using \( M_{Sun} = 1.99 \times 10^{30} \) kg, \( M_{Earth} = 5.97 \times 10^{24} \) kg, \( R_{Sun} = 6.961 \times 10^{8} \) m, \( R_{Earth} = 6.38 \times 10^{3} \) m and \( T_{Earth} = 6000 \) K \([21]\) (there are many different published values for the temperature, we think this value is reasonable). There are many different temperature values of the Sun. We use the values \( T_{Sun} = 15.7 \times 10^{6} \) K of the solar center \([22]\). From Formula \((20)\), we get the constant \( C = 8.58 \times 10^{2} \). We can use Formula \((20)\) as a phenomenological temperature formula of the universe center to estimate the temperature of the contracted universe center.

Using \( M_{U} = 1.0 \times 10^{53} \) kg from \((14)\), then \( M_{Earth} \) is the mass of the earth, and \( R_{Earth} \) is the radius of the earth. In order to get useful values, we assume the radius of the contracted universe \( R_{U} = 2.24 \times 10^{4} \) m, the temperature \( T_{U} \) of the center of the universe is
\[
T_{U} = C \frac{M_{U}}{M_{Earth}} \frac{R_{Earth}}{R_{U}} T_{Earth} = 4.1 \times 10^{30} K,
\]
(21)
and corresponding to this temperature energy \( E_{T} \)
\[
E_{T} = (3/2)kT = 8.5 \times 10^{7} J,
\]
(22)
where \( k \) is Boltzmann constant, \( k = 1.38 \times 10^{-27} J K^{-1} \).

From \((13)\), we have the binding energy of a baryon at the center of the universe by the whole contracted universe \( U(b,U) = - \frac{2GM_{U}m_{b}}{R} \). Using \( M_{U} = 1.0 \times 10^{53} \) kg, \( m_{b} = 1.67 \times 10^{-27} \) and \( R = 2.24 \times 10^{4} \) m, we get
\[
U(b,U) = - \frac{2GM_{U}m_{b}}{R} = -9.95 \times 10^{11} J.
\]
(23)
From \([22]\), the total binding energy \( E_{Tot} \) of each baryon is
\[
E_{Tot} = E_{T} + U(b,U) = 8.5 \times 10^{7} J - 9.95 \times 10^{11} J = -9.95 \times 10^{11} J.
\]
(24)
Formula (24) shows that although the universe contracts to the small ball with radius \( R = 2.24 \times 10^4 \) m, its temperature is as high as \( T_U = 4.1 \times 10^{30} \) K, with associated its energy \( E_T = 8.5 \times 10^7 \) J, and the baryons in the universe cannot overcome the gravitational binding energy (-9.95 \times 10^{11} J) to get free from the ball. It still needs more than 9.95 \times 10^{11} J of energy for any baryon (p or n) to create the Big Bang. When the \( R_U \) contracts, the temperature is higher from (21), and the energy \( E_T \) is higher from (22); but from (13) the binding energy will increase with the contraction. The increased heat (T) energy \( E_T \) of the contracted universe is completely canceled by the increased binding energy \( U(b, U) \). Thus the total binding energy \( E(WU) \) of the whole contracted universe with \( R = 2.24 \times 10^4 m \) and mass \( M = 1.0 \times 10^{53} \) is

\[
E(WU) = E_{Tot} \times N_{b,U} = -9.95 \times 10^{11} J \times \frac{1.0 \times 10^{53}}{1.67 \times 10^{-27}} = -5.96 \times 10^{91} J.
\]  

Therefore the total energy \( E(WU) \) produced by the contracted universe is a negative energy, -5.94\times 10^{91} J, it cannot make the Big Bang as shown in Table 1.

| \( R_U \) (m) | 2.24\times 10^{-26} | 2.24\times 10^{-6} | 2.24 | 2.24\times 10^{4} | 2.24 \times 10^{8} |
|----------------|-----------------|----------------|------|----------------|----------------|
| \( \overline{\rho} \text{ (kg/m}^3) \text{)} \text{ (15)} | 2.13\times 10^{129} | 2.13\times 10^{69} | 2.13\times 10^{51} | 2.13 \times 10^{39} | 2.13\times 10^{27} |
| \( T_U \) (K) \text{ (21)} | 4.1 \times 10^{60} | 4.1 \times 10^{40} | 4.1 \times 10^{34} | 4.1 \times 10^{30} | 4.1 \times 10^{26} |
| \( E_T \) (J) \text{ (22)} | 8.5 \times 10^{37} | 8.5 \times 10^{17} | 8.5 \times 10^{11} | 8.5 \times 10^{7} | 8.5 \times 10^{3} |
| \( U_{b,U} \) (J) \text{ (23)} | -9.95 \times 10^{41} | -9.95 \times 10^{21} | -9.95 \times 10^{15} | -9.95 \times 10^{11} | -9.95 \times 10^{7} |
| \( E_{Tot} \) (J) \text{ (24)} | -9.95 \times 10^{41} | -9.95 \times 10^{21} | -9.95 \times 10^{15} | -9.95 \times 10^{11} | -9.95 \times 10^{7} |
| \( E(WU) \) (J) \text{ (25)} | -5.96 \times 10^{121} | -5.96 \times 10^{101} | -5.96 \times 10^{95} | -5.96 \times 10^{91} | -5.96 \times 10^{87} |

In order to show the contraction of the universe cannot produce the Big Bang, we list the to-
tal energy $E(WU)$ values that will be produced by the corresponding contracted radius $R_U$ values as shown in Table 1. In Table 1, the numbers in the parentheses of the first column (15), (21), (22), (23), (24) and (25) are the numbers of formulae. Table 1 shows that although the contraction of the universe really can produce extremely high density $\bar{\rho}(kg/m^3)$ from (15) and high temperature $T_U(K)$ from (21), at the same time it can produce much larger binding energy $U_{b,U}(J)$ from (23) also. The final total result is the $E_{T,d}(J)$ from (24) for each baryon.

For the whole universe, the total energy of the universe $E(WU)$ from (25) is shown on the last row of Table 1. The total energy $E(WU)$ produced by the contracted universe can not produce the Big Bang since the total energy is always negative. As the contracted size of the universe becomes smaller, the total energy becomes larger (absolutely value), and the production of the Big Bang becomes much more difficult. The contracted universe, however, can pull the negative energy quarks out from the quark Dirac sea to prepare the “fuel” for the Big Bang.

### 4.3 The binding energy of a quark inside the quark Dirac sea

The interactions among the quarks inside the quark Dirac sea are electromagnetic interactions, strong interactions and gravitational interactions. The strong interactions are the strongest. It mainly determines and holds the structure of the quark Dirac sea together. Our purpose primarily is to find the strong binding energy of the quark now. We do not know how to calculate it directly. Thus we calculate the electromagnetic binding energy of the quark first, then using strong interactions are 137 times larger than electromagnetic ones to estimate indirectly strong bind energy of the quark by the quark Dirac sea. Since electrons do not have strong interactions, we omit them and only consider the quarks. We will find the electromagnetic binding energy of the quark in the quark Dirac sea first.
4.3.1 Estimating electromagnetic binding energy of a quark in the quark Dirac sea

In the quark Dirac sea, the u-quarks have $Q = 2/3$ and the d-quarks have $Q = -1/3$, they interact each other. This is a many-body problem. It cannot be resolve precisely. We have to use an approximate method. The quark Dirac sea is composed of a huge number domains. There is a piece of body-central cubic quark lattice in each domain as shown in Figure 1 (a). In the body-central cubic quark lattice, each u-quark always have eight nearest neighbor d-quarks and each d-quark always have eight nearest nearest u-quarks as shown in Figure 2 (b). The quarks at centers have opposed electric charges with the nearest neighbor quarks at the corners. The simplest approximation is the nearest neighbor approximation. In this approximation, for any quark, we only consider its eight nearest neighbor quarks (omit all of other quarks) since other quarks with positive charges nearby negative charges contribute to the binding energy approximately cancel with each other. In the body-central cubic quark lattice, for any d-quark with $Q = -1/3$, there are always eight nearest neighbor u-quarks with $Q = +2/3$ (see Fig. 2 (b)) and for any u-quark with $Q = +2/3$, there are always eight nearest neighbor d-quarks with $Q = -1/3$. Thus in the nearest neighbor approximation, for any quark (u or d), the binding energy $u(e,q) = u(e,d) = u(e,u)$ is

\[ u(e,q) = u(e,d) = u(e,u) = 8 \frac{K Q_{cen} Q_{cor}}{d} = -2.92 \times 10^7 (J), \]  

(26)

where $K = 8.98755 \times 10^9$ N m$^2$ C$^{-2}$, $Q_{cen} = (-1/3)1.60 \times 10^{-19}$C, $Q_{cor} = +(2/3)1.60 \times 10^{-19}$C and $d = (\sqrt{3}/2)a$. Where “a” is the lattice constant (“a”= the Planck length = $1.62 \times 10^{-35}$ m from Postulate III). Formula (26) shows that any quark has approximately the same binding energy $u(e,q) = u(e,u) = u(e,d) = - 2.92 \times 10^7 (J)$. 

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4.3.2 Estimating the strong binding energy of a quark inside the quark Dirac sea

We can not directly calculate the strong binding energy of a quark in the QDS since the quark Dirac sea is a many body system; we have to use an approximation method to estimate the quark strong binding energy. Because three nearest neighboring quarks have white color without strong interactions with other quarks. Thus we use the nearest neighbor approximation to consider only the eight nearest quarks and omit all other quarks. Although using the nearest neighbor approximation, we still can not directly calculate the strong binding energy of the quark with eight nearest neighbor quarks since this is a many body problem. Additional the high temperature, the high density, the high pressure and the small distance \((10^{-35} \text{ m})\) altogether further increase the difficult of the calculation. Fortunately, we have already found the electromagnetic binding energy \([26]\) between the quark and its eight nearest quarks. For simplicity, using strong interactions are 137 times larger than the electromagnetic interactions, we rough estimate the strong binding energy \(U(s)\) between the quark and its eight nearest neighbor quarks:

\[
U(s) = 137u(e, q) = -4.00 \times 10^9 \, (J).
\]  

(27)

4.3.3 Estimating the gravitational potential energy of a quark in the quark Dirac sea

Any quark in the quark Dirac sea has “relatively infinite” quarks around it. The “relatively infinite” quarks have “relatively infinite” mass. Thus the quark has a “relatively infinite” gravitational potential energy \(U(G)\); it is the same everywhere since the quark Dirac sea is homogenous and isotropic. We take the potential energy \(U(G)\) as the energy zero point from Postulate VI.

\[
U(G) = 0.
\]  

(28)
Thus the gravity energy is the same anywhere, and the gravitational field $F_G$ equals zero anywhere.

### 4.3.4 Estimating the total binding energy of a quark in the quark Dirac sea

A quark inside the quark Dirac sea has the electromagnetic binding energy $u(e,q) = -2.94 \times 10^7 (J)$ from (26) and the strong binding energy $U(s) = -4.00 \times 10^9 (J)$ from (27) as well as the gravitational potential energy $U(G) = 0$ from (28). Thus the total binding energy $U(T)$ is

$$U(T) = u(e,q) + U(s) + U(G) = -4.03 \times 10^9 (J)$$  \hspace{1cm} (29)

We have already found the binding energy $U(T)$ of a quark inside the quark Dirac sea (29), and we have already calculated the gravitational pulling energy of the quark inside the QDS by the universe (13). Comparing the two kinds of energies, we can find the condition for a quark to be pulled out from the QDS. The condition is that the absolute value $|U(cent)|$ of the gravitational pulling energy on the quark is larger than the absolute value $|U(T)|$ of the binding energy of the quark inside the quark Dirac sea.

### 4.4 The contracted universe pulls a huge amount of quarks and anti-quarks out from the quark Dirac sea with its gravity

Formula (11) shows that the universe’s pulling energy of a quark in the QDS proportions to $\frac{1}{R}$. This means that the universe’s pulling energy (absolute value) increases as the universe’s radius $R$ decreases. Since the binding energy of a quark in the quark Dirac sea is negative and the pulling energy of the quark from the universe is negative too, once the pulling energy’s absolute value ($|U(center)|$) is larger than the binding energy’s absolute value ($|U(T)| = 4.03 \times 10^9 J$) of the
quark in the quark Dirac sea, the quark will be pulled out from the quark Dirac sea. Here we omit the energy $E_T$ of the temperature from contraction of the universe (about 0.01 % from Table 1).

$$|U(\text{cent})| \geq |U(T)| \rightarrow \frac{2GM_0m_q}{R} \geq 4.03 \times 10^9 J.$$  

About the initial mass $M_0$ of the universe we do not know; we are not sure whether the dark matter and dark energy exist before the Big Bang. For simplicity, we assume that before the Big Bang the universe has only the observable mass of the current universe $M_0 = M_U = 1.0 \times 10^{53} \text{kg}$ from [14]; where $m_q = 3.80 \text{ Mev}$ is the average mass of u-quarks ($m_u = 2.55$) and d-quarks ($m_d = 5.04$) [12]. Thus we have

$$R \leq \frac{2GM_Um_q}{4.03 \times 10^9} = 2.24 \times 10^4 m.$$  

When $R \leq 2.24 \times 10^4 \text{ m}$, the quark at the center of the universe ball (the quark with negative energy inside the quark Dirac sea in the vacuum) is pulled out from the quark Dirac sea by the gravity of the universe. After the quark at the center of the universe is pulled out from the quark Dirac sea, then: 1). The quarks binding energy on the eight former nearest neighbor quarks in the quark Dirac sea decreases by $\frac{1}{8}$. This is a big amount. 2). The universe’s pulling energy absolute value($\frac{2GM_Um_q}{R}\left(1 - \frac{r_0}{2R}\right)$) on the eight former nearest neighbor quarks in QDS decrease $\frac{0.866a}{2R}$ = $1.26 \times 10^{-30} (J)$ than $U(\text{center}) \geq 4.03 \times 10^{11} J$ since $r_0 = \frac{\sqrt{3}}{2}a$ (this is very small and can be omitted). Thus the former nearest eight neighbor quarks are pulled out from the quark Dirac sea also since the gravity force is the same as before but the binding force decreases by $\frac{1}{8}$. Similarly, the former nearest neighbor quarks of the former eight nearest neighbor quarks are pulled (excited) out from the quark Dirac sea too. The process continues . . . . . 3). Until the universe expands to its size larger enough and the pulling energy (absolute value) small enough (small than $4.03 \times 10^9 J$) which can not pull quark out the quark Dirac sea any more, the pulled quark process stop. The
precise number of the pulled quarks are unknown, but we do know the number is huge and the number of pulled antiquarks is huge also, furthermore the number of the pulled quarks equals the number of the pulled antiquarks. The pulled huge number of quarks and antiquarks will combine into baryons and release a huge amount of energy to produce the Big Bang.

5 The Quark Energy Produces the Big Bang

When the universe contracts to the critical size with \( R = 2.24 \times 10^4 \) m, the universe pulls a huge number of quarks and antiquarks from the quark Dirac sea. The excited huge amount of quarks and antiquarks are the fuel to produce the energy needed by the Big Bang. Let us estimate how many excited quarks and antiquarks can make the current expanding universe.

5.1 How many excited quarks and antiquarks can make the current expansion of the universe

In order to know how many excited quarks and antiquarks can make the current expansion, we have to know the whole binding energy of the contracted universe at the critical size \( R = 2.24 \times 10^4 \) m. In this paper, we will usually use estimated values to illustrate our physical ideas. We do not claim to be accurate for our estimates. In fact, some astronomical values cannot be given accurate values right now, we have to estimate them.

5.1.1 Estimating the whole binding energy of the universe at critical size

From Formula (21), the contracted universe at the critical radius \( R = 2.24 \times 10^4 \) m has \( T_U = 4.1 \times 10^{30} K \). The temperature provides energy \( E_T = \frac{3kT}{2} = 8.5 \times 10^7 J \) for a baryon from Formula (22). From
Formula (13), the pulling energy of a baryon by the universe $U(b, U) = -9.95 \times 10^{11} \text{J}$ for a baryon. The total binding energy of a baryon inside the universe is $E_{\text{Tol}} = E_T + U(b, U) = 8.5 \times 10^7 \text{J} - 9.95 \times 10^{11} \text{J} = -9.95 \times 10^{11} \text{J}$. Thus the whole universe with mass $1.0 \times 10^{53} \text{kg}$ has total binding energy $E(WU) = -5.96 \times 10^{91} \text{J}$ from (25).

Without energy comes from outside, the universe cannot expand. The energy of making the Big Bang is from the excited quarks and antiquarks. In order to know how many excited quarks and antiquarks can produce the energy needed by the expansion of the current universe, we have to know how much energy can be released when three quarks combine into one baryon and three antiquarks combine into one antibaryon as well as when one baryon-antibaryon pair annihilates.

### 5.1.2 How much energy can be released when three quarks (antiquarks) combine into a baryon (antibaryon) and one quark-antiquark pair annihilates?

The three excited quarks combine into a baryon and release energy, and the three excited antiquarks combine into an antibaryon and release the same quantity of energy. How much energy can be released when three quarks (antiquarks) combine into a baryon (antibaryon)?

This is a very difficult problem. Directly measuring the released energy is not possible right now. In fact physicists have tried to separate baryons to get free quarks for many decades, so that we have some information about the energy to separate the quarks inside the baryon. Physicists have already used the accelerators that have the highest energy 980 Gev in Fermilab (Tevatron 1978-present and Tevatron II 2001-present) for many years. No individual free quark has been found [23]. This kinds of accelerators (980 Gev) cannot free the quarks from baryons. This means that the energy (980 Gev) cannot separate the quarks in baryons. The cosmic rays with much higher energy than the energy (980 Gev) steel cannot separate the quarks in baryons also. Thus
we estimate the released energy of three quarks combining into a baryon is much larger than the 980 Gev. If we want to separate a baryon with 100% possibility, we need much higher energy than the energy (980 Gev). Therefore we roughly estimate the three quarks binding energy $E_{\text{release}}$ (= $E_{\text{melt}}$ that can separates baryon into quarks and gluons) is about

$$E_{\text{release}} > 980 \text{ Gev}.$$  \hfill (32)

Formula (32) show that three quarks combine into a baryon to release an energy (much more than 980 Gev ) and three antiquarks combine into an antibaryon to release an energy (much more than 980 Gev) also. Then the baryon-antibaryon pair annihilates back the quark Dirac sea and release 1878 Mev (two baryons with energy 939+939 Mev) energy at least. The total released energy $E(b + \bar{b} + b\bar{b})$ of the excited three quarks and the three antiquarks as well as a baryon-antibaryon pair will be

$$E(b + \bar{b} + b\bar{b}) \gg 1962 \text{ Gev} = 3.14 \times 10^{-7} J.$$ \hfill (33)

Formula (33) shows that three quarks combine into a baryon and the three antiquarks combine into an antibaryon as well as a baryon-antibaryon pair annihilates together to release much more than $3.14 \times 10^{-7} J$ energy.

### 5.1.3 How much energy can be released from a pair $q\bar{q}$ annihilation?

How much energy can be released from a pair $q\bar{q}$ annihilation? From Formula (33), the three quarks combine into a baryon and the three antiquarks combine into an antibaryon as well as a baryon-antibaryon pair annihilates together to release more than $3.14 \times 10^{-7} J$ energy.

Since a baryon is composed of three quarks and an antibaryon is composed of three antiquarks, one baryon-antibaryon pair is equivalents to three quark-antiquark pairs. Thus we guess that one
quark-antiquark pair annihilation can releases energy, from Formula (33), as

\[ E(q\bar{q}) = \frac{E(b + \bar{b} + b\bar{b})}{3} > 654 \text{Gev} = 1.05 \times 10^{-7} \text{J}. \]  (34)

Formula (34) shows that one quark-antiquark pair annihilation can release energy \( E(q\bar{q}) \) much larger than \( 1.05 \times 10^{-7} \text{J} \).

5.1.4 How many excited quarks are need to make the current expanded universe?

From Formula (25), we know that the whole observable contracted universe with mass \( M = 1.0 \times 10^{53} \text{ kg} \), at \( R = 2.24 \times 10^{4} \text{ m} \) has binding energy \( E(WU) = - 5.96 \times 10^{91} \text{J} \). Formula (34) gives that one quark-antiquark pair annihilation can release energy \( E(q\bar{q}) \) much larger than \( 1.05 \times 10^{-7} \text{J} \). Thus we need

\[ N(q) = N(\bar{q}) < \frac{5.96 \times 10^{91} \text{J}}{1.05 \times 10^{-7} \text{J}} = 5.68 \times 10^{98}. \]  (35)

The excited quark number \( N(q) \) equals the excited antiquark number \( N(\bar{q}) \) is much smaller than \( 5.68 \times 10^{98} \). The number is the needed number of quarks and antiquarks which can release enough energy to push the observable matter of the universe \( (1.0 \times 10^{53} \text{ kg}) \) to infinity with no kinetic energy.

This matter \( (1.0 \times 10^{53} \text{ kg}) \) is the observable matter of the universe. It does not include the dark matter and dark energy. The dark matter and the dark energy have 96% percent of the total matter of current universe, while the observable matter is 4% of the total matter of current universe. If we push all matter (including dark matter and dark energy) to infinity, we need more excited quarks \( N(q,D) \) and antiquarks \( N(\bar{q}, D) \):

\[ N(q, D) = N(\bar{q}, D) < \frac{5.96 \times 10^{91} \text{J}}{1.05 \times 10^{-7} \text{J}} \times \frac{100}{4} = 1.42 \times 10^{100}. \]  (36)
We do not know how many excited quarks are needed in the Big Bang from the starting expansion to the present state, but we can guess that the real needed number \( N(\text{Need}) \) is smaller than the number \( N(q,D) \leq 1.42 \times 10^{100} \) since the universe has not expanded to infinite yet, and it will be larger than \( N(q) = 5.68 \times 10^{98} \) since the total mass of the current universe is much larger (24 times) than the observable mass of the universe, we guess it may more than \( N(q) \).

\[
5.68 \times 10^{98} < N(\text{Need}) < 1.42 \times 10^{100}.
\]  

(37)

Formula (37) gives the needed excited quark number range \( 5.68 \times 10^{98} - 1.42 \times 10^{100} \). A huge number of the excited quarks and antiquarks are pulled out from the quark Dirac sea in a very short time.

### 5.2 Loading up the fuel (quarks and antiquarks) for the Big Bang

When the universe contracts to its critical size \( R = 2.24 \times 10^4 \) m, three processes start:

1). The universe pulls quarks and antiquarks out from the quark Dirac sea; adding the mass to the universe (and the pulling force of the universe) and decreasing the binding energy of the nearest former remaining quarks in the quark Dirac sea; so that the pulling quark process continues progressing.

2). The excited (pulled) quarks (antiquarks) combine into baryons (antibaryons) and release energy since three reasons: First, under usual temperature, ordinal pressure and normal gravitational field, the “melting-point” of baryon (the temperature at which baryons can be separated into quarks and gluons) is unknown high (much high than 980 Gev, from (32)). Second, although the contracted universe with \( R = 2.24 \times 10^4 \) m has very high temperature \( (4.1 \times 10^{30} \text{K} \rightarrow E_T = 8.5 \times 10^7 \text{J}) \) which may melt baryons and obstruct quarks combine into baryons. There is, however,
the gravitational energy \( U(b, U) = -9.95 \times 10^{11} \) J which has canceled the \( E_T \) and help the quarks to combine baryons. Third, the very high density \( (\rho = 2.13 \times 10^{39} \text{kg}) \) and the very strong gravitational field of the contracted universe produce very high pressure to help that the quarks combine into the baryons. In fact, there is really a huge amount energy to produce the Big Bang, this energy cannot come from the atoms and nuclei, it is only comes the quarks. The quark energy is really produced and really makes the Big Bang.

3). The released energies start and accelerate the expansion of the universe. The universe’s size \( (R) \) becomes larger and larger, and the universe pulling force becomes smaller and smaller. Until the size reaches a new critical value \( R^* \) and \( M_0^* \), the universe pulling energy (absolute value) from Formula (13) will be smaller than the binding energy (absolute value) of the quark Dirac sea in Formula (29), and the universe cannot pull out quark any more.

\[
\left| \frac{2GM_0^*m_q}{R^*} \left( 1 - \frac{r_0}{2R^*} \right) \right| < |U(T)| = 4.03 \times 10^9 \text{(J)}
\] (38)

where \( m_0^* \) is the mass of the universe at \( R = R^* \); it includes the observable mass and the mass of the excited quarks (and the excited antiquarks).

In this period, the main job is loading the fuel for the Big Bang. The fuel is the excited quarks and antiquarks that are pulled out from the quark Dirac sea by the contracted universe using its gravity. From Formula (37), the total excited quark number is about \( 5.68 \times 10^{99} \text{–} 1.42 \times 10^{100} \). Since the process is incredibly fast, the time of the process is incredibly short. When the process of the universe pulling quarks is finished, this means the loading fuel period is over, and a new period is coming.
5.3 The explosive accelerated expansion of the universe

After the loading of the fuel, the universe has a huge amount of fuel (excited quarks and antiquarks). The excited quarks and antiquarks are expanding with the original matter of the universe, so that the quarks and antiquarks broadcast everywhere in the universe. In order to understand the real state of the universe, we can estimate the broadcasted quark density. We assume that when the universe expands to radius $R^* = 100R = 2.24 \times 10^6 \text{m}$ and the excited quark number equals half $N(\text{Need})$ in Formula (37), the volume of the universe $V = \frac{4\pi}{3}(2.24 \times 10^6 \text{m})^3 = 4.71 \times 10^{19} \text{m}^3$. Using $N(q,D) = 1.42 \times 10^{100}$ from (36), we get

$$\rho(\text{upper}) = 0.5 \frac{N(q,D)}{4.71 \times 10^{19} \text{m}^3} = 1.51 \times 10^{80} \text{m}^{-3}. \quad (39)$$

Using $N(q) = 5.68 \times 10^{98}$ from (35), we get

$$\rho(\text{lower}) = 0.5 \frac{N(q)}{4.71 \times 10^{19} \text{m}^3} = 6.03 \times 10^{78} \text{m}^{-3}. \quad (40)$$

Formula (39) and Formula (40) show the density up limit and down limit. The density is very high, under the strong interactions, the excited quarks and antiquarks have explosive quark reactions. In order to precisely express the meaning of “nearby”, we define: if two particles are inside the strong interactions range (about $10^{-15} \text{m}$), then we call them nearby particles. If a quark has a nearby antiquark, they will annihilate and release energy; if three quarks (uud or udd) are nearby with each other, they will combine into a baryon and release energy; if three antiquarks ($\overline{uud}$, or $\overline{udd}$) are nearby with each other, they will combine into an antibaryon and release energy; if an antibaryon has a nearby baryon they will annihilate and release energy. Since there are a huge number of quarks and a huge number of antiquarks, the above processes will continuously explosive progress, and the speed of the expansion of the universe will accelerate faster and faster until the
nearby quark-antiquark pairs run out, the nearby quarks run out, the nearby antiquarks run out, then the explosive accelerating engine stop. Although the explosive acceleration time is very short, a huge quantity of energy $E_{\text{Out}}$ has already released in this period. The universe in this process is like the explosion of a bomb; but the energy of the universal Big Bang is much larger than a hydrogen bomb.

In order to see this case, we can estimate the released energy $E_{\text{Out}}$ of the quarks and the antiquarks. We assume 95 percent of the total needed quarks and antiquarks have been used in the period. From Formula (37) and Formula (33), the released energy range $\text{Range}(E_{\text{Out}})$ is

$$\text{Range}(E_{\text{Out}}) = 0.95 \frac{N(\text{need})}{3} \times E(b + \bar{b} + b\bar{b}) = 5.65 \times 10^{91} J \rightarrow 1.41 \times 10^{93} J.$$  

(41)

Formula (41) gives the released energy region $5.65 \times 10^{91} J - 1.41 \times 10^{93} J$. This is a huge energy that is enough to overcome the gravity of the universe and to produce the Big Bang. Explaining the origin of the energy of the Big Bang is the main purpose of this paper.

After the fast expansion dilutes the distribution of the quarks and antiquarks, the density of the excited quarks and antiquarks becomes much smaller. A very slowly accelerated period is coming.

5.4 A very slow acceleration and a very fast expansion period

At the end of the explosive accelerated expansion period, the quark (or antiquark) density has already become very small. Although the density is very small, the total excited quark number is still huge (about 5 percent of total needed quarks $5.68 \times 10^{98} - 1.42 \times 10^{100} = 2.83 \times 10^{97} - 7.10 \times 10^{99}$).

Although the acceleration is very small, the speed of the expansion is large. The large expansion of the universe dilutes the distribution of the excited quarks, as the time passes, the density of the
quarks and antiquarks becomes smaller and smaller; the released quark energy becomes smaller and smaller; as a result, the acceleration becomes smaller and smaller. Maybe the acceleration is difficult to be found. We do not know how long this process will take.

In fact, many physicists have searched for free quarks for more than thirty years, no free quark has been found [23]. This means there is no free quark. Thus the observable acceleration of the expansion of the universe now is not from the quarks. The quark acceleration has already finished. If the observable acceleration is really come from the quarks, today observed acceleration may be produced long time ago since the light needs time to travel to the earth. Because of the current experiments have not found any individually quark.

5.5 The future of the universe

The current universe is in a state of slowly accelerating expansion. The future of the universe is uncertain. It depends on how long the acceleration can keep up. If the acceleration can keep up forever, then the universe will expand forever. If the acceleration can keep up for only a finite time, the gravity of the universe will stop the expansion and the gravity will recontract the universe again. Thus, the universe will be cyclic: the universe will undergo a series of cycles, each beginning with a big bang and ending with a big crunch [7] [8].

6 Discussion

Now that the quark Dirac sea really exists in the vacuum, why has it not been discovered?

The quark Dirac sea has not been discovered because of at least six reasons:

First, because the lattice constant of the quark Dirac sea $a = (1.62 \times 10^{-35} m)$ and the sizes of
the domains are much smaller than the limit of the distance scale of the standard model $10^{-18}m$ [11]. The domains are distributed completely randomly in positions and in directions of symmetry axes of the lattices. The QDS appears as a homogeneous and isotropic as well as “continuous” space.

Second, there are no net electric charge, no net color charge, no the gravitational potential and no the gravitational field ($V_G = 0$ and $F_G = 0$ from Postulate VI) at any physical point inside the quark Dirac sea. Thus, physicists cannot use electric or strong or gravitational interactions to discover the neutral quark Dirac sea. The QDS appears as a completely “empty” space.

Third, the quarks (u-quarks or d-quarks) in the quark Dirac sea are bound by the strong attractive forces and Coulomb’s attractive forces with energy ($4.03 \times 10^9 (J)$ (29)). It is a super-strong structure. Even nuclear fusion energy (about 10 Mev = $10^{-12} J$) is not enough to change the quark Dirac sea for detection. Thus it looks like it can never be changed. No change means no chance to be discovered.

Fourth, from Formula (13) we can estimate the pulling energy of a baryon at the center of the earth, the Sun and the Milky Way with $R = 10^3 m$. We get $E_{\text{earth}} = - \frac{2GM_{\text{earth}}mb}{R} = - 1.33 \times 10^{-15} J$; $E_{\text{Sun}} = - \frac{2GM_{\text{Sun}}mb}{R} = 4.43 \times 10^{-10} J$; $E_{\text{MilkyWay}} = - \frac{2GM_{\text{MilkyWay}}mb}{R} = - 2G \times 5.8 \times 10^{11} M_{\text{Sun}}mb = - 5.43 \times 10^2 J$. These energies represent the pulling energies of planets, stars and galaxies. All the pulling energies are much smaller than the banding energy ($4.03 \times 10^9 (J)$ (29)) of the quark Dirac sea. All celestial bodies pulling energy can be omitted. The quark Dirac sea looks as “empty” since a huge galaxy contracted to very small size with $R = 1000 m$ cannot pull a quark out from it.

Fifth, the ideal lattices do not scatter a particle moving inside it [16]. The lattices inside the domains of the QDS are all the ideal lattices. The QDS appears as a no scattering space.

Sixth, the quark Dirac sea is a “relatively infinite” homogeneous and isotropic system. All sci-
cientific observations, experiments and research occurs within the quark Dirac sea. This (“relatively infinite” system) has limited the scientists from comparing the current case with the other case without the quark Dirac sea to find the quark Dirac sea.

Despite, the above obstacle, in fact scientists have already discovered some clues of the quark Dirac sea. For example, high energy physical experiments have discovered large numbers of particle pairs \((e\bar{e}, p\bar{p} \text{ and } n\bar{n})\) created out from the vacuum and annihilated back to the vacuum. This is a clue that the quark Dirac sea exists. If there is no quark Dirac sea, where do these particles come from?

7 Conclusions

1. The contraction of the universe cannot produce the Big Bang as Table 1 has shown. We have to expand the original Dirac sea (including electrons only) to the quark Dirac sea (QDS) including negative energy \(u\)-quarks and \(d\)-quarks as well as electrons in the vacuum.

2. There is a huge number of domains of the body-central cubic quark lattice with the size much smaller than \(10^{-18}\text{m}\). They are completely randomly distributed in positions and directions of the symmetry axes of the lattices in the domains fully over the QDS. In the lattice, each primitive cell contains two quarks (\(u\) and \(d\)), the nearest three cells contain an electron. Its lattice constant is the Planck length “\(a\)” = \(1.62\times10^{-35}\text{m}\).

3. The QDS is homogeneous, isotropic and “continuous”. There is no net electric charge, no net color charge, no gravitational potential \((V_{QD} = 0)\) and no gravitational field \((F_G = 0)\) at any physical point in the QDS. The particles are moving in the QDS likes they are moving in a stable and non-scattering space. It is a warehouse of \(e\bar{e}, u\bar{u}, d\bar{d}, p\bar{p}\) and \(n\bar{n},\ldots,\) pairs. Therefore the quark
Dirac sea is a perfect model of the vacuum.

4. The contracted universe pulls out a huge number of quarks and antiquarks from the QDS by its gravity at its critical size. This is a necessary and sufficient condition for the Big Bang.

5. The huge number of excited quark-antiquark pairs annihilate(s) back to the QDS and release a huge amount of energy; the huge number of excited quarks combine into baryons and release a huge amount of energy; the huge number of antibaryons combine into antibaryons and release a huge amount of energy; then the $B\bar{B}$ pairs annihilate back to the QDS and release a huge amount of energy also. Together, these huge quark energies make the Big Bang.

6. The Big Bang theory depends on two major assumptions: the universality of physical laws and the Cosmological Principle. The Cosmological Principle states that on large scales the universe is homogeneous and isotropic. Thus, the homogeneous and isotropic quark Dirac sea provides a firmly physical foundation for the Cosmological Principle. So that, the quark Dirac sea provides a physical firm foundation for the Big Bang theory.

7. The present universe is expanding from a finite size universe with a radius $R = 2.24 \times 10^4$ m, not from the singularity with an infinite density and temperature.

8. It provides a strong support of the quark model that only the quark energy can make the Big Bang.

8. In astronomy there are many important physical quantities that cannot be precisely measured now. We have estimated many quantities to illustrate our physical ideas. We are not sure the accuracy of our estimates. They are not the results of precise measurements or accurate theory deduction. They are only phenomenological estimates.
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