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The Light-Dark Dual Universe for the Big Bang and Dark Energy

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ABSTRACT

In the proposed light-dark dual universe, the light universe is the observable universe with light and kinetic energy that fueled the Big Bang, and the dark universe without light and kinetic energy has been observed as dark energy since about 9 billion years after the Big Bang. The light-dark dual universe started from the zero-energy universe through the four-stage cyclic transformation. Emerging from the zero-energy universe, the four-stage transformation consists of the 11D (dimensional) positive-negative energy dual membrane universe, the 10D positive-negative energy dual string universe, the 10D positive-negative energy dual particle universe, and the 4D (light)-variable D (dark) positive-negative energy dual particle asymmetrical universe. The transformation can then be reversed back to the zero-energy universe through the reverse four-stage transformation. The light universe is an observable four-dimensional universe started with the inflation and the Big Bang, and the dark universe is a variable dimensional universe from 10D to 4D. The dark universe could be observed as dark energy only when the dark universe turned into a four-dimensional universe. The four-stage transformation explains the four force fields in our universe. The theoretical calculated percentages of dark energy, dark matter, and baryonic matter are 72.8. 22.7, and 4.53, respectively, in nearly complete agreement with observed 72.8, 22.7, and 4.56, respectively. According to the calculation, dark energy started in 4.47 billion years ago in agreement with the observed 4.71 ± 0.98 billion years ago. The zero-energy cyclic universe is based on the space-object structures.

Keywords: Cosmology; Light Universe; Dark Universe; Dual Universe; Big Bang; Inflation; Zero-Energy; Cyclic Universe; Dark Energy; Dark Matter; Baryonic Matter; Force Fields

1. Introduction

The Big Bang has kinetic energy, while dark energy does not have kinetic energy. It is possible that they come from two different universes. In the proposed dual universe, the Big Bang comes from the observable "light universe" with light and kinetic energy, and dark energy comes from the "dark universe" without light and kinetic energy. Dark energy did not occur at the time of the Big Bang. Dark energy emerged after about 9 billion years following the Big Bang. In other words, the dark universe was not observable from the light universe for 9 billion years. It is proposed that for about 9 billion years the dark universe as the higher space-time dimensional universe was not observable by the light universe as the four-dimensional universe, because the observation violated causality [1] as explained later. When the variable dimensional dark universe from 10D (dimensional) to 4D turned into four-dimensional space-time after about 9 billion years following the Big Bang, the dark universe became observable as dark energy.

Therefore, the creation of our universe started with the formation and the separation of the four-dimensional light universe with light and kinetic energy and the variable dimensional dark universe from 10D to 4D without light and kinetic energy. This complicated light-dark dual universe, obviously, could not emerge by itself without simple predecessor universes. The ultimate predecessor universe of the light-dark dual universe before the creation is the zero-energy universe without form and energy.

In the zero-energy universe hypothesis, the total amount of energy in the universe is exactly zero. The conventional zero-energy universe hypothesis is based on quantum fluctuation and the exact cancellation of positive-

energy matter by negative-energy gravity through pseudotensor [2] or the inflation [3] before the Big Bang. Quantum fluctuation provides a natural explanation for how that energy may have come out of nothing in the universe. Throughout the multiverse, from the zero-energy universe, symmetrical positive-energy and negative-energy universes spontaneously form and quickly annihilate each other. A negative universe becomes a negative energy gravitational field, and a positive energy universe becomes positive-energy matter as described by Stephen Hawking in A Brief History of Time [4]: "The positive energy of the matter is exactly balanced by the negative energy of the gravitational field. So the universe can start off with zero energy and still create matter."

In the proposed zero-energy cyclic universe, the positive-negative energy dual universe with the zero-sum energy emerges from zero-energy, and the universe undergoes a cyclic transformation. The negative-energy universe is not in the form of negative-energy gravity. Several cyclic universe models have been proposed [5]. For our universe, the cyclic transformation is between the 11D universe and the 4D universe. Emerging from the zero-energy universe, the cyclic transformation from the 11D universe to the 4D universe involves the four-stage transformation consisting of the 11D positive-negative energy dual membrane universe, the 10D positive-negative energy dual string universe, the 10D positive-negative energy dual particle universe, and the 4D (light)-variable D (dark) positive-negative energy dual particle asymmetrical universe as **Figure 1**.

As explained later, each stage provides the origin of a force field, so the four-stage transformation provides the origins for the four force fields, the strong, the gravitational, the electromagnetic, and the weak force fields, chronologically, for our universe. Our current universe is the 4D (light)-variable D (dark) positive-negative energy dual particle asymmetrical universe.

As explained later, all universes with the space-time dimension number higher than 4 have non-zero vacuum energies, so before the creation of our universe, the predecessor positive-negative energy dual universes had non-zero vacuum energies proportional to the space-time dimension numbers, and they had no light. The transition from the non-zero vacuum energy to the zero vacuum energy in the light universe constituted the inflation before the Big Bang, and the introduction of kinetic energy in the light universe led to the Big Bang.

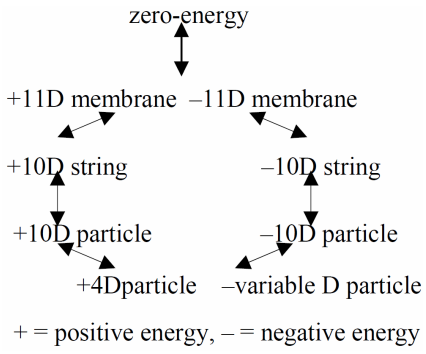

Figure 1. The zero energy cyclic universe.

Baryonic matter and dark matter are in the light universe, and dark energy comes from the dark universe and the bulk space between the light and the dark universes. As shown later, the theoretical calculated percentages of dark energy, dark matter, and baryonic matter are in nearly complete agreement with observed values. The theoretical calculation of the years to start dark energy is also in agreement with the observed value.

2. The Space-Object Structures

The zero-energy cyclic universe is based on the space-object structures [1]. Different universes are the different expressions of the space-object structures.

The space structure [6] consists of attachment space (denoted as 1) and detachment space (denoted as 0). Attachment space attaches to object permanently with zero speed. Detachment space detaches from the object at the speed of light. Attachment space relates to rest mass, while detachment space relates to kinetic energy. Different stages of our universe have different space structures.The transformation between mass (massive particle) in attachment space and kinetic energy (massless particle) in detachment space is through the scalar Goldstone boson.

The object structure consists of 11D membrane (3_{11}), 10D string (2_{10}), particle ($1_{4\text{ to }10}$), and empty object ($0_{4\text{ to }11}$). Different universes and different stages of a universe can have different expressions of the object structure. The transformation among the objects is through the dimensional oscillation [1] that involves the oscillation between high dimensional space-time and low dimensional space-time based on the varying speed of light. Varying speed of light has been proposed to explain the horizon problem of cosmology [7,8]. J. D. Barrow [9] proposes that the time dependent speed of light varies as some power of the expansion scale factor a in such way that

$$c(t) = c_0 a^n, \tag{1}$$

where $c_0 > 0$ and n are constants. The increase of speed of light is continuous.

In this paper, varying dimension number (VDN) relates to quantized varying speed of light (QVSL), where the speed of light is invariant in a constant space-time dimension number, and the speed of light varies with varying space-time dimension number from 4 to 11.

$$c_{\mathrm{D}} = c/\alpha^{\mathrm{D}-4}, \tag{2}$$

where c is the observed speed of light in the 4D space-time, c_{D} is the quantized varying speed of light in space-time dimension number, D, from 4 to 11, and α is the fine structure constant for electromagnetism. Each dimensional space-time has a specific speed of light. (Since from the beginning of our observable universe, the space-time dimension has always been four, there is no observable varying speed of light in our observable universe.) The speed of light increases with the increasing space-time dimension number D.

In special relativity, $E = M_0 c^2$ modified by Equation (2) is expressed as

$$E = M_0 \cdot \left(c^2 / \alpha^{2(\mathrm{D}-4)} \right) \tag{3a}$$

$$= \left(M_0 / \alpha^{2(\mathrm{d}-4)} \right) \cdot c^2 . \tag{3b}$$

Equation (3a) means that a particle in the D dimensional space-time can have the superluminal speed $c/\alpha^{\mathrm{D}-4}$, which is higher than the observed speed of light c, and has the rest mass M_0. Equation (3b) means that the same particle in the 4D space-time with the observed speed of light acquires $M_0/\alpha^{2(\mathrm{d}-4)}$ as the rest mass, where d = D. D from 4 to 11 in Equation (3a) is the space-time dimension number defining the varying speed of light. In Equation (3b), d from 4 to 11 is "mass dimension number" defining varying mass. For example, for D = 11, Equation (3a) shows a superluminal particle in eleven-dimensional space-time, while Equation (3b) shows that the speed of light of the same particle is the observed speed of light with the 4D space-time, and the mass dimension is eleven. In other words, 11D space-time can transform into 4D space-time with 11d mass dimension. 11D4d in Equation (3a) becomes 4D11d in Equation (3b) through QVSL. QVSL in terms of varying space-time dimension number, D, brings about varying mass in terms of varying mass dimension number, d. Mass dimension is also proposed in the Wesson's Space-Time-Matter (STM) theory as the matter dimension to account for the extra space dimensions [10].

The QVSL transformation transforms both space-time dimension number and mass dimension number. In the QVSL transformation, the decrease in the speed of light leads to the decrease in space-time dimension number and the increase of mass in terms of increasing mass dimension number from 4 to 11,

$$c_{\mathrm{D}} = c_{\mathrm{D}-n} / \alpha^{2n}, \tag{4a}$$

$$M_{0,\mathrm{D,d}} = M_{0,\mathrm{D}-n,\mathrm{d}+n} \alpha^{2n}, \tag{4b}$$

$$\mathrm{D,d} \xrightarrow{\mathrm{QVSL}} (\mathrm{D} \mp n), (\mathrm{d} \pm n) \tag{4c}$$

where D is the space-time dimension number from 4 to 11 and d is the mass dimension number from 4 to 11. For example, in the QVSL transformation, a particle with 11D4d is transformed to a particle with 4D11d. In terms of rest mass, 11D space-time has 4d with the lowest rest mass, and 4D space-time has 11d with the highest rest mass.

Rest mass decreases with increasing space-time dimension number. The decrease in rest mass means the increase in vacuum energy, so vacuum energy increases with increasing space-time dimension number. The vacuum energy of 4D particle is zero, while 11D membrane has the Planck vacuum energy. On the other hands, the vacuum space dimension number of 11D membrane is zero, while the vacuum space dimension number of 4D particle is 7.

Since the speed of light for >4D particle is greater than the speed of light for 4D particle, the observation of >4D superluminal particles by 4D particles violates casualty. Thus, >4D particles are hidden particles with respect to 4D particles. Particles with different space-time dimensions are transparent and oblivious to one another, and separate from one another if possible.

3. Cosmology

The transformation from the 11D universe to the 4D universe involves the four-stage transformation consisting of the 11D positive-negative energy dual membrane universe, the 10D positive-negative energy dual string universe, the 10D positive-negative energy dual particle universe, and the 4D-variable D positive-negative energy dual particle asymmetrical universe which provide the origins for the strong, the gravitational, the electromagnetic, and the weak force, respectively.

The multiverse starts with the zero energy universe, which produces the positive energy 11D membrane universe and the negative energy 11D membrane universe denoted as 3_{11} 3_{-11}, as proposed by Mongan [11]. The only force among the membranes is the pre-strong force, s, as the predecessor of the strong force. It is from the quantized vibration of the membranes to generate the reversible process of the absorption-emission of the particles among the membranes. The pre-strong force mediates the reversible absorption-emission in the flat space. The pre-strong force is the same for all membranes, so it is not defined by positive or negative sign.

In certain regions of the 11D membrane universe, the local expansion takes place by the transformation from 11D-membrane into 10D-string. The expansion is the result of the vacuum energy difference between 11D membrane and 10D string. With the emergence of empty object (0_{11}), 11D membrane transforms into 10D string warped with virtue particle as pregravity.

$$3_{11} s + 0_{11} \leftrightarrow 2_{10} s 1_1 = 2_{10} s g^+ \tag{5}$$

where 3_{11} is the 11D membrane, s is the pre-strong force,

0_{11} is the 11D empty object, 2_{10} is 10D string, 1_1 is one dimensional virtue particle as g, pre-gravity. Empty object corresponds to the anti-De Sitter bulk space in the Randall-Sundrum model [12] for gravity. In the same way, the surrounding object can extend into empty object by the decomposition of space dimension as described by Bounias and Krasnoholovets [13], equivalent to the Randall-Sundrum model. The g is in the bulk space, which is the warped space (transverse radial space) around 2_{10}. As in the AdS/CFT duality [14] for gravity, the pre-strong force has 10D dimension, one dimension lower than the 11D membrane, and is the conformal force defined on the conformal boundary of the bulk space.

Through symmetry, antistrings form 10D antibranes with anti-pregravity as $2_{-10}\, g^{-}$, where g^{-} is anti-pregravity.

$$3_{-11}s + 0_{-11} \leftrightarrow 2_{-10}s1_{-1} = 2_{-10}sg^{-} \tag{6}$$

Pregravity can be attractive or repulsive to anti-pregravity. If it is attractive, the universe remains homogeneous. If it is repulsive, n units of $(2_{10})_n$ and n units of $(2_{-10})_n$ are separated from each other.

$$\left(\left(s2_{10}\right)g^{+}\right)_n\left(g^{-}\left(s2_{-10}\right)\right)_n \tag{7}$$

The dual 10D string universe consists of two parallel universes with opposite energies: 10D strings with positive energy and 10D antistrings with negative energy. The two universes are separated by the bulk space, consisting of pregravity and anti-pregravity. There are four equal regions: positive energy string universe, pregravity bulk space, anti-pregravity bulk space, and negative energy antistring universe. Such dual universe separated by bulk space appears in the ekpyrotic universe model [15].

Through the dimensional oscillation, the 10D dual universe returns to the 11D dual universe that coalesces to undergo annihilation and to return to the zero energy universe. The 10D positive and negative universe can also coalesce to undergo annihilation and to return to the zero energy universe. The first path of such coalescence is the annihilation, resulting in disappearance of the dual universe and the return to the zero-energy universe.

The second path allows the continuation of the dual universe in another form without annihilation from the mixing of positive energy and negative energy. Such dual universe is possible by the emergence of the pre-charge force, the predecessor of electromagnetism with positive and negative charges that provide the new distinction between string and antistring. The mixing of string and antistring becomes the mixing of positive charge string and negative charge antistring instead of positive energy string and negative energy antistring, resulting in the preservation of the dual universe with the positive energy and the negative energy. The process is the charge transformation as **Figure 2**.

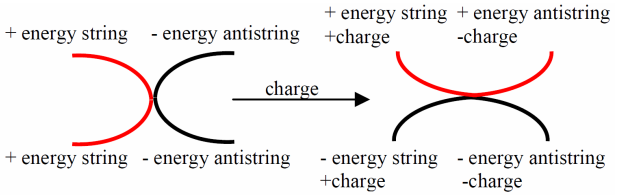

Figure 2. The charge transformation.

During the coalescence for the second path, the positive energy string and the negative energy antistring intersect at the middle as **Figure 2**. The combination of one half of the positive energy and one half of the negative energy antistring form a new string. As a result, there are two new strings with the top half and with the bottom half of **Figure 2**. The top half is transformed into a new positive energy string, while the bottom half is transformed into a new negative energy string. The way to achieve such transformations is through the emergence of charges in the charge transformation. In the top half of the figure above, a positive charge (e+) emerges in the positive energy string, and a negative charge (e−) emerges in the negative energy antistring to transform the negative energy antistring into the positive energy antistring, resulting in the positive energy antistring with negative charge. The new string from the top half includes the positive energy positive charge string and positive energy negative charge antistring.

Simultaneously, in the bottom half of the figure above, a negative charge emerges in the negative energy antistring, and a positive charge emerges in the positive energy string to transform the positive energy string into the negative energy string, resulting in the negative energy string with positive charge. The new string from the bottom half includes the negative energy negative charge antistring and the negative energy positive charge string. In the charge transformation, all transformations and the additions of charges are symmetrical.

At that time, the space (detachment space) for radiation has not appeared in the universe, so the string-antistring annihilation does not result in radiation. The string-antistring annihilation results in the replacement of the string-antistring as the 10D string-antistring, $(2_{10}\ 2_{-10})$ by the 10D particle-antiparticle $(1_{10}\ 1_{-10})$. The 10D particles-antiparticles have the multiple dimensional Kaluza-Klein structure with variable space dimension number without the requirement for a fixed space-time dimension number as 10 for string-antistring. After the mixing, the dual 10D particle-antiparticle universe separated by pregravity and anti-pregravity appears as below.

$$\left(\left(s1_{10}e^{+}e-1_{-10}s\right)g^{+}\right)_n\left(g^{-}\left(s1_{10}e^{+}e-1_{-10}s\right)\right)_n, \tag{8}$$

where s and e are the pre-strong force and the pre-charged force in the flat space, g is pregravity in the bulk

space, and $1_{10}\ 1_{-10}$ is the particle-antiparticle.

The dual 10D particle universe consists of two parallel particle-antiparticle universes with opposite energies and the bulk space separating the two universes. There are four equal regions: the positive energy particle-antiparticle universe, the pregravity bulk space, the negative energy particle-antiparticle universe, and the anti-pregravity bulk space.

The formation of our current universe follows immediately after the formation of the charged pre-universe through the asymmetrical dimensional oscillations and the asymmetrical addition of detachment space, leading to the asymmetrical dual universe. The asymmetrical dimensional oscillation involved the immediate transformation of the positive-energy universe from 10D to 4D and the slow stepwise reversible transformation of the negative-energy universe between 10D and 4D. The result was the asymmetrical dual universe consisting of the positive-energy 4D light universe with kinetic energy and light and the negative-energy oscillating 10D-4D dark universe without kinetic energy and light. The light universe contains both attachment space and detachment space.

The asymmetrical dual universe is manifested as the asymmetry in the weak interaction in our observable universe as follows.

$$\begin{array}{l}\text{Light Universe and bulk space}\\ \left(\left(s1_4 e^+ w^+ e^- w - 1_{-4} s\right) g^+\right)_n\\ \text{Dark Universe and bulk space}\\ \left(g^-\left(s1_{4\text{ to }10} e^+ w^+ e^- w - 1_{-4\text{ to }-10} s\right)\right)_n\end{array} \tag{9}$$

where s, g, e, and w are the strong force, gravity, electromagnetism, and weak interaction, respectively for the observable universe, and where $1_4\ 1_{-4}$ and $1_{4\text{ to }10}\ 1_{-4\text{ to }-10}$ are 4D particle-antiparticle for the light universe and variable D particle-antiparticle for the dark universe, respectively.

The dark universe involves the stepwise two-step transformation: the QVSL transformation and the varying supersymmetry transformation from 10D4d to 4D4d (The particles in the 10D dual particle universe are 10D4d). The QVSL transformation involves the transformation of space-time dimension, D. The varying supersymmetry transformation involves the transformation of the mass dimension number, d, as follows.

$$\begin{array}{l}\text{stepwise two-step varying transformation}\\ (1)\ \mathrm{D,d} \xleftrightarrow{\text{QVSL}} (\mathrm{D}\mp 1),(\mathrm{d}\pm 1)\\ (2)\ \mathrm{D,d} \xleftrightarrow{\text{varying supersymmetry}} \mathrm{D},(\mathrm{d}\pm 1)\end{array} \tag{10}$$

The repetitive stepwise two-step transformation from 10D4d to 4D10d as follows:

$$\begin{array}{l}10\mathrm{D4d} \to 9\mathrm{D5d} \to 9\mathrm{D4d} \to 8\mathrm{D5d} \to \cdots \to 4\mathrm{D5d} \to 4\mathrm{D4d}\\ \mapsto \text{hidden dark universe} \leftarrow\mapsto \text{dark energy} \leftarrow\end{array}$$

In this two-step transformation, the transformation from 10D4d to 9D5d involves the QVSL transformation as in Equation (4c). Calculated from Equation (4b), the mass of 9D5d is $1/\alpha^2 \approx 137^2$ times of the mass of 10D4d. The transformation of 9D5d to 9D4d involves the varying supersymmetry transformation. In the normal supersymmetry transformation, the repeated application of the fermion-boson transformation carries over a boson (or fermion) from one point to the same boson (or fermion) at another point at the same mass. In the "varying supersymmetry transformation", the repeated application of the fermion-boson transformation carries over a boson from one point to the boson at another point at different mass dimension number in the same space-time number. The repeated varying supersymmetry transformation carries over a boson $\mathrm{B_d}$ into a fermion $\mathrm{F_d}$ and a fermion $\mathrm{F_d}$ to a boson $\mathrm{B_{d-1}}$, which can be expressed as follows

$$M_{\mathrm{d,F}} = M_{\mathrm{d,B}}\alpha_{\mathrm{d,B}}, \tag{11a}$$

$$M_{\mathrm{d-1,B}} = M_{\mathrm{d,F}}\alpha_{\mathrm{d,F}}, \tag{11b}$$

where $M_{\mathrm{d,\,B}}$ and $M_{\mathrm{d,\,F}}$ are the masses for a boson and a fermion, respectively, d is the mass dimension number, and $\alpha_{\mathrm{d,B}}$ or $\alpha_{\mathrm{d,F}}$ is the fine structure constant that is the ratio between the masses of a boson and its fermionic partner. Assuming α's are the same, it can be expressed as

$$M_{\mathrm{d,B}} = M_{\mathrm{d+1,B}}\alpha^2_{\mathrm{d+1}}. \tag{11c}$$

The mass of 9D4d is $\alpha^2 \approx (1/137)^2$ times of the mass of 9D5d through the varying supersymmetry transformation. The transformation from a higher mass dimensional particle to the adjacent lower mass dimensional particle is the fractionalization of the higher dimensional particle to the many lower dimensional particles in such way that the number of lower dimensional particles becomes

$$N_{\mathrm{d-1}} = N_{\mathrm{d}}/\alpha^2 \approx N_d\,(137)^2 \tag{11d}$$

The fractionalization also applies to D for 10D4d to 9D4d, so

$$N_{\mathrm{D-1}} = N_{\mathrm{D}}/\alpha^2 \tag{11e}$$

Since the supersymmetry transformation involves translation, this stepwise varying supersymmetry transformation leads to a translational fractionalization, resulting in the cosmic expansion. Afterward, the QVSL transformation transforms 9D4d into 8D5d with a higher mass. The two-step transformation repeats until 4D4d, and then reverses stepwise back to 10D4d.

In the light universe, the dimensional oscillation transforms 10D to 4D immediately. It involves the two-step

transformation: the QVSL transformation and the slicing by detachment space. The Big Bang occurred afterward.

$$\begin{aligned}&10\text{D4d} \xrightarrow{\text{quick QVSL transformation}} 4\text{D10d}\\ &\xrightarrow{\text{slicing with detachment space,}} \text{dark matter}\\ &\left(4\text{D9d}+4\text{D8d}+4\text{D7d}+4\text{D6d}+4\text{D5d}\right)\\ &+\text{baryonic matter}\,(4\text{D4d})+\text{cosmic radiation}\\ &\rightarrow \text{thermal cosmic expansion}\left(\text{the Big Bang}\right)\end{aligned} \tag{12}$$

This two-step transformation corresponds to the two-step inflation. In the first step, the quick and immediate QVSL transformation transforms 10D4d from the 10D dual particle universe to 4D10d immediately. Calculated from Equation (4b), the mass of 4D10d is $1/\alpha^{12} \approx 137^{12}$ times of the mass of 10D4d, resulting in the first step of the inflation as the rapid expansion of space from the high vacuum energy 10D4d to the zero vacuum energy 4D10d.

The first step of the inflation does not involve kinetic energy. The second step introduces kinetic energy (detachment space) in the slicing of particles for the reduction of the mass dimension number. Bounias and Krasnoholovets [16] propose another explanation of the reduction of >4 D space-time into 4D space-time by slicing >4D space-time into infinitely many 4D quantized units surrounding the 4D core particle. Such slicing of >4D space-time is like slicing 3-space D object into 2-space D object in the way stated by Michel Bounias as follows: "You cannot put a pot into a sheet without changing the shape of the 2-D sheet into a 3-D dimensional packet. Only a 2-D slice of the pot could be a part of sheet".

The slicing is by detachment space, as a part of the space structure, which consists of attachment space (denoted as 1) and detachment space (denoted as 0) as described earlier. Attachment space for rest mass attaches to object permanently with zero speed. Detachment space for kinetic energy detaches from the object at the speed of light. The cosmic origin of detachment space is the cosmic radiation from the particle-antiparticle annihilation that initiates the transformation. The cosmic radiation cannot permanently attach to a space.

The slicing of dimensions is the slicing of mass dimensions. 4D10d particle is sliced into six particles: 4D9d, 4D8d, 4D7d, 4D6d, 4D5d, and 4D4d equally by mass. Baryonic matter is 4D4d, while dark matter consists of the other five types of particles (4D9d, 4D8d, 4D7d, 4D6d, and 4D5d). The mass ratio of dark matter to baryonic matter is 5 to 1 in agreement with the observation [17] showing the universe consists of 22.7% dark matter, 4.56% baryonic matter, and 72.8% dark energy.

Detachment space (0) involves in the slicing of mass dimensions. Attachment space is denoted as 1. For example, the slicing of 4D10d particles into 4D4d particles is as follows:

$$\begin{aligned}&\left(1_{4+6}\right)_i\\ &10\text{d attachment} \xrightarrow{\text{slicing by detachment space}}\\ &\text{space}\\ &\left(1_4\right)_i \qquad \sum_1^6\left(\left(0_4\right)\left(1_4\right)\right)_{j,6}\\ &\text{4d core} \qquad \text{6 types of 4d units}\\ &\text{attachment} \qquad \text{force fields}\end{aligned} \tag{13}$$

The two products of the slicing are the 4d-core attachment space and 6 types of 4d quantized units. The 4d core attachment space surrounded by 6 types of many (j) 4D4d quantized units corresponds to the core particle surrounded by 6 types of many small 4d particles, which constitute gauge force fields in "dimensional orbitals" [18]. The dimensional orbitals of baryonic matter provide the base for the periodic table of elementary particles to calculate accurately the masses of all 4D elementary particles, including quarks, leptons, and gauge bosons [18].

As shown in Reference [18], baryonic matter has electromagnetism (charge), while dark matter does not have electromagnetism. Without electromagnetism, dark matter cannot emit light, and is incompatible to baryonic matter, like the incompatibility between oil and water. After the creation of the light-dark dual universe, baryonic matter and dark matter started to separate from each other gradually. Millions years afterward, stars started to appear from baryonic matter. The increasing incompatibility between dark matter and baryonic matter leads to the inhomogeneity like emulsion, resulting in the formation of stars, galaxies, clusters, and superclusters [19]. Dark matter has not been found by direct detection because of the incompatibility that does not allow the direct contact with dark matter by baryonic matter.

The second step (the slicing) introduced detachment space as kinetic energy, and generated baryonic matter, dark matter, and cosmic radiation. The detailed description of the inflation is described in Reference [19]. The resulting kinetic energy started the thermal cosmic expansion as the Big Bang.

The dark universe consists of two periods: the hidden dark universe and the dark energy universe. The hidden dark universe composes of the >4D particles. As mentioned before, particles with different space-time dimensions are transparent and oblivious to one another, and separate from one another if possible. Thus, >4D particles are hidden and separated particles with respect to 4D particles in the light universe (our observable universe). The hidden dark universe with D > 4 and the observable universe with D = 4 are the "parallel universes".

The 4D particles transformed from hidden >4D particles in the dark universe are observable dark energy for the light universe, resulting in the accelerated expanding universe. Since the dark universe does not have detach-

ment space, the presence of dark energy is not different from the presence of the cosmological constant. In terms of quintessence, such dark energy can be considered the tracking quintessence [20] from the dark universe with the space-time dimension number as the tracker. Dark energy emerged about 5 billion years ago (more precisely 4.71 ± 0.98 billion years ago at z = 0.46 ± 0.13) [21]).

The four regions in the light-dark dual universe include the light universe, the gravity bulk space, the antigravity bulk space, and the dark universe. Through the symmetry among the space regions, all regions expand synchronically and equally (The symmetry is necessary for the ultimate reversibility of all cosmic processes). The light universe is the only region with the four-dimensional space-time and with kinetic energy from the beginning, and all other three regions have variable dimensional space-time without kinetic energy. The light universe occupies 25% of the total universe, while the other regions occupy 75% of the total universe, so the maximum dark energy from the dark universe, the gravity bulk space, and the antigravity bulk space is 75%. The present observable universe about reaches the maximum (75%) at the observed 72.8% dark energy [17]. At 72.8% dark energy, the calculated values for baryonic matter and dark matter (with the 1:5 ratio) are 4.53% (=(100 – 72.8)/6) and 22.7% (=4.53 × 5), respectively, in excellent agreement with observed 4.56% and 22.7%, respectively [17].

Our universe is 13.7 billion-year old. Dark energy as the transformation from 5D to 4D started in about 4.71 ± 0.98 billion years ago [21]. The ratio of the time periods for the transformations from D → D − 1 is proportional to ln of the total number of particles (Equation (11e)) to be transformed from D → D – 1 for the exponential growth with time as **Table 1**.

The period of the 5D → 4D is (0.333) (13.7)/((0.333) (72.8/75) + 0.667) = 4.61 billion years, and dark energy as the 5D → 4D started in (4.61) (72.8/75) = 4.47 billon years ago that is in agreement with the observed value of 4.71 ± 0.98 billion years ago [21].

After the maximally connected universe, 4D dark energy transforms back to >4D particles that are not observable. The removal of dark energy in the observable universe results in the stop of accelerated expansion and the start of contraction of the observable universe. The end of dark energy starts another "parallel universe period". Both hidden universe and observable universe contract synchronically and equally. Eventually, the Big Crush and the two-step deflation occur in the light universe. In the first step of the deflation, the light universe loses all detachment space, kinetic energy, light, cosmic radiation, and force fields as dimensional orbitals, resulting in the return to 4D10d. In the second step of the deflation, the increase in vacuum energy allows the zero vacuum energy 4D10d to become the high vacuum energy 10D4d. Meanwhile, hidden >4D particles-antiparticles in the hidden universe transform into 10D4d particles-antiparticles. The dual universe can undergo another cycle of the light-dark dual universe. On the other hand, both universes can undergo the reverse charge transformation to become the 10D dual string universe, which in turn can return to the 11D dual membrane universe that in turn can return to the zero-energy universe as **Figure 3**.

4. Summary

The light-dark dual universe is based on the two physical structures: the space structure and the object structure. The space structure includes attachment space and detachment space. Relating to rest mass, attachment space attaches to object permanently with zero speed. Relating to kinetic energy, detachment space detaches from the object at the speed of light. The object structure consists of 11D membrane (3_{11}), 10D string (2_{10}), particle ($1_{4\text{ to }10}$), and empty object ($0_{4\text{ to }11}$). The transformation among the objects is through the dimensional oscillation that involves the oscillation between high dimensional space-time with high vacuum energy and low dimensional space-time with low vacuum energy. Our observable universe with 4D space-time has zero vacuum energy. Different universes in different developmental stages are the different expressions of the two physical structures.

In the proposed light-dark dual universe, the light universe is the observable universe with light and kinetic energy that fueled the Big Bang, and the dark universe without light and kinetic energy has been observed as dark energy since about 9 billion years after the Big Bang. The light-dark dual universe started from the zero-energy universe through the four-stage cyclic transformation. Emerging from the zero-energy universe, the four-stage transformation consists of the 11D (dimen-

Table 1. The percentages of the periods in the dark universe.

	10D → 9D	9D → 8D	8D → 7D	7D → 6D	6D → 5D	5D → 4D
Ratio of total numbers of particles	1	α^{-2}	α^{-4}	α^{-6}	α^{-8}	α^{-10}
Ratio of ln (total number of particles)	0	-2α	-4α	-6α	-8α	-10α
Ratio of periods	~0	1	2	3	4	5
Percentages of periods	~0	6.7	13.3	20	26.7	33.3

α is the fine structure constant for electromagnetism from Equation (11e).

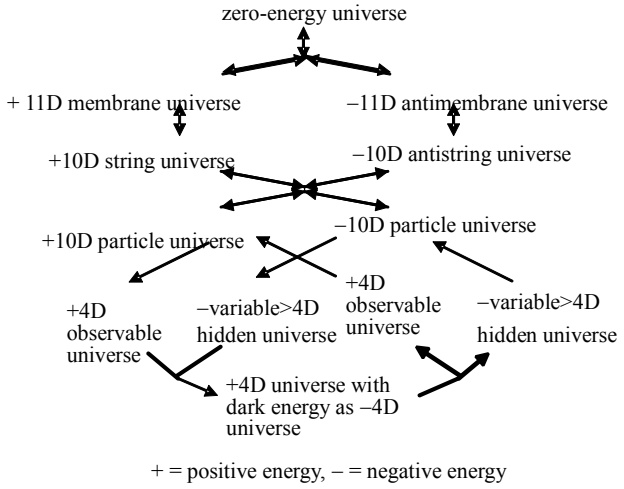

Figure 3. The cyclic cosmology.

sional) positive-negative energy dual membrane universe, the 10D positive-negative energy dual string universe, the 10D positive-negative energy dual particle universe, and the 4D (light)-variable D (dark) positive-negative energy dual particle asymmetrical universe. The transformation can then be reversed back to the zero-energy universe through the reverse four-stage transformation. The light universe is an observable four-dimensional universe started with the inflation and the Big Bang, and the dark universe is a variable dimensional universe from 10D to 4D. The dark universe could be observed as dark energy only when the dark universe turned into a four-dimensional universe. The four-stage transformation explains the four force fields in our universe. The theoretical calculated percentages of dark energy, dark matter, and baryonic matter are 72.8. 22.7, and 4.53, respectively, in nearly complete agreement with observed 72.8, 22.7, and 4.56, respectively. According to the calculation, dark energy started in 4.47 billion years ago in agreement with the observed 4.71 ± 0.98 billion years ago.

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