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Large Scale Fundamental Interactions in the Universe

Qiao Bi

Department of Physics, Science School, Wuhan University of Technology, Wuhan, China
Email: biqiao@gmail.com

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Abstract

The author of this paper once attempted to propose a unified framework for gauge fields based on the mathematical and physical picture of the principal fiber bundle: that is, to believe that our universe may have more fundamental interactions than the four, and these fundamental gauge fields are only components on the bottom manifold (*i.e.* our universe) projected by a unified gauge potential of the principal fiber bundle manifold; these components can satisfy the transformation of gauge potential, or even be transformed from one basic interaction gauge potential to another basic interaction gauge potential, and can be summarized into a unified equation, namely the generalized gauge equation expression, corresponding to gauge transformation invariance; so the invariance of gauge transformation is a necessary condition for unified field theory, and the four (or more) fundamental interaction fields of the universe are unified in a unified gauge field defined by the connection on the principal fiber bundle. In this paper, the author continues to propose a model of large-scale (gravitational) fundamental interactions in the universe based on the mathematical and physical picture of the principal fiber bundle, attempting to explain that dark matter and dark energy are merely reflections of these gravitational fundamental interactions that deviate in intensity from the gravitational fundamental interactions of the solar system at galaxy scales or some cosmic scales which are much larger than the solar system. All these "gravitational" fundamental interactions originate from the unified gauge field of the universe, namely the connection or curvature on the principal fiber bundle. These interactions are their projected representations on the bottom manifold (*i.e.* our universe) by different cross-sections (gauge transformations). These projection representations of the universe certainly are described by the generalized gauge equation or curvature similarity equation, and under the guidance of curvature gauge transformation factors, oscillate and evolve between the curvatures $1 \to 0 \to -1 \to 0 \to 1$ of the universe.

Keywords

Principal Bundle, Gauge Similarity Transformation, Dark Matter and Dark Energy, Large-Scale Fundamental Interaction, Evolution of Universe

1. Introduction

Dark matter and dark energy are the two biggest secrets and important frontier issues in the cosmology of physics in our era. Currently, this topic can be mainly divided into two major academic viewpoints. The first viewpoint holds that dark matter and dark energy are the main components of matter and energy in the universe; in the composition of the entire universe, conventional matter (*i.e.* baryonic matter) accounts for only 4.9%, while dark matter accounts for 26.8%, and 68.3% is dark energy (mass energy equivalent) [1] [2] [3]. Dark matter does not interact with electromagnetic forces, that is, it does not absorb, reflect, or emit light. At present, people can only know through the effects generated by gravity, which are mysterious and universally distributed. The detection of dark matter is a hot research field in contemporary particle physics and astrophysics. For massive weakly interacting particles, physicists may directly detect them by placing detectors in underground laboratories with extremely low background noise, or indirectly detect other particles generated by the annihilation of these particles at the center of galaxies, sun, or Earth through ground or space telescopes. In November 2015, Gary Prézeau, a scientist at NASA's Jet Propulsion Laboratory, also used the Lambda Cold Dark Matter model to simulate the flow of dark matter through planets such as Earth and Jupiter in the Milky Way. He found that this would significantly increase the density of the dark matter flow (for example, Earth is: 10^7 times, Jupiter is: 10^8 times), and exhibit a hairlike outward radiation distribution structure [4] [5]. However, although dark matter is currently the most popular theory in explaining observations of various galaxies and galaxy clusters, there is still no direct observational evidence to support the existence of dark matter [6]. As for dark energy, the main evidence is currently believed to be that the observed universe is accelerating expansion. Currently, it is generally assumed that dark energy is isotropic in the universe, has a very low density, and only interacts with gravity without electromagnetic, strong, or weak forces. The density of dark energy is as low as approximately 10^{-29} g/cm^3, making it difficult for laboratories on Earth to directly detect it. However, because dark energy fills all space, accounting for 68.3% of the total mass and energy of the universe, it significantly affects the overall evolution of the universe [7] [8] [9].

The second viewpoint holds that dark matter and dark energy do not exist at all, but are merely illusory manifestations of human cognitive or measurement errors; perhaps the Newton or Einstein theory of gravity, which we believe to be absolutely correct, is not complete, and gravity behaves differently at different scales of time and space. Among them, the interesting one is the Gravity Theory Correction (MOND) hypothesis, which modifies Newton's formula of universal gravitation as an alternative dark matter theory to explain the problem of galaxy rotation. This theory was founded by Israeli physicist Modze Milgrom in 1983 [10]. Currently, there are two main types of dark matter theories to explain dark energy, namely the cosmological constant theory and the basic scalar field theory, and both contain two important properties of dark energy, namely uniformity and negative pressure [11] [12] [13] [14] [15]. But at present, physics still cannot truly explain which type of energy by dark energy acts on the spatiotemporal structure itself, and how does this sort of energy also generate uniform negative pressure, leading to accelerated expansion of the spatiotemporal structure? What is the mechanism behind this [16]?

For the first viewpoint, the author does not want to make a negative evaluation, but the author believes that the biggest problem with it is that it has been going through many years, with humans spending a huge amount of money, scientists spending a huge amount of energy and time, and so far there is no direct evidence of dark matter or dark energy. What does it mean that a universal distribution of matter and energy, which accounts for over 95% of the universe, should exist in large quantities around us but cannot be detected?

The author agrees with the second viewpoint in terms of direction. But the problem is that the theoretical hypotheses related to systematicity still need to be updated and developed. For example, why does Newton's Second Law fail at the scale of galaxies? What is the physical meaning of adding the cosmological constant term to the Einstein equation? Is there an overall connection between the dark matter problem and the dark energy problem? That's exactly what this paper aims to explore and answer. Moreover, this paper aims to construct a structural picture of large-scale basic interactions in the universe from a holistic perspective, exploring the sources of dark matter and dark energy, as well as the direction of cosmic evolution.

The tool used in this paper is the mathematical and physical theory of the principal fiber bundle [17] [18] [19]. The author believes that our universe, in a sense, is like a bottom manifold of principal bundle and various interactions are like connections or curvature on this bottom manifold, corresponding to the physical essence of gauge potential or gauge field strength. These gauge potentials or gauge field strengths are influenced by the scale of the manifold region, and their relationship with each other is given by the generalized gauge equation or the gauge similarity transformation [17] [18] [19]. The real determining factor in the universe is the principal bundle structure built on this bottom manifold. It can also be seen as a direct product manifold of the universe (*i.e.* bottom manifold) and the rules of universe (*i.e.* structure group), combined with numerous complicated mappings, which is a manifold with higher dimensions than the universe. Its connection or curvature just corresponds to a unified gauge field in the universe, which is invariant to the gauge transformation [17].

The remaining parts of this paper are organized as follows: Section 2 describes the physical and mathematical landscape of the Principle Bundle. In Section 3, the physical essence of dark matter and dark energy are studied in detail. The two branch evolution of universe is detail proposed. In Section 4, a brief discussion on the large-scale kinematic equations of the universe is presented. In Sections 5 - 6, the secret of the cosmic term in the Einstein equation is discussed. Lastly, conclusions and expectation are given in Section 7.

2. The Physical and Mathematical Picture of the Principal Bundle

The differential geometric representation of the mathematical and physical picture of the principal bundle mentioned above in this paper can be referred to references [17] [18] [19] [20], and will not be repeated here for simplicity. But here, in order to ensure that the calculations related to general relativity can be directly applied without being affected, it is possible to assume that the bottom manifold M in the frame bundle $P(M,G)$ has an adapted metric field, and this frame field can have orthogonal normalization properties. That is, if the dimension of M is $n=4$, the adapted Riemann metric field or Lorentz metric field can be applied on it, and $P\equiv\left\{\left(x,\hat{e}_\mu\right)|\,x\in M\right\}$, where $\hat{e}_\mu$ represents an orthogonal normalized basis in the tangent space T_xM, and then selecting matrix groups $SO(4)$ or $O(1,3)$ as a structure group, the group elements can undergo orthogonal normalized frame transformations, so that obtained principal bundle can be defined as an orthogonal normalized frame bundle.

A connection on the principal bundle $P(M,G)$ is a C^∞ 1-form field $\boldsymbol{\omega}_U$ of the Lie algebra $\mathcal{G}$-value specified by a local trivial $T_U:\pi^{-1}[U]\to U\times G$ on U, namely it is a connection on $U\subset M$. At this time, if $T_V:\pi^{-1}[V]\to V\times G$ is another local trivial, $U\bigcap V\neq\varnothing$, and $\exists$ the conversion function g_{UV} from the local trivial T_U to T_V, then the generalized Gauge equation is held [15], namely

$$\boldsymbol{\omega}_V(Y)=\mathcal{A}d_{g_{UV}(x)^{-1}}\boldsymbol{\omega}_U(Y)+L^{-1}_{g_{UV}(x)*}g_{UV*}(Y),\ \forall x\in U\bigcap V, Y\in T_xM \tag{1}$$

where $L^{-1}_{g_{UV}(x)}$ is an inverse mapping of left translation $L_{g_{UV}(x)}$ generated by $g_{UV}(x)\in G$, and the asterisk represents the forward mapping with $L^{-1}_{g_{UV}(x)*}\equiv\left(L^{-1}_{g_{UV}(x)}\right)_*$.

Furthermore, this principal bundle structure consists of a structure group, a principal bundle manifold, and a base manifold. The cross-section of the principal bundle is the gauge potential, and the curvature is the gauge field strength, satisfying the curvature gauge transformation relationship between two different regions U and V. For example, generally speaking, if $g_{UV}:U\bigcap V\to G$ is a conversion function of local trivial transition from T_U to T_V, and $\boldsymbol{\Omega}_V$ and $\boldsymbol{\Omega}_U$ is the curvature of the V region or the U region on the bottom manifold, then on $U\bigcap V$ there is

$$\mathbf{\Omega}_V = \mathcal{A}d_{g_{UV}^{-1}}\mathbf{\Omega}_U \tag{2}$$

where, $\mathcal{A}d_{g_{UV}^{-1}}$ is the forward mapping from Lie algebra $\mathcal{G}$ to $\mathcal{G}$, which is induced by the adjoin isomorphism $I_{g_{UV}^{-1}}$ defined by the group element g_{UV}^{-1} of structure group G with Lie algebra $\mathcal{G}$.

If the structure group is a matrix group, then Equation (2) can be further expressed as:

$$\mathbf{\Omega}_V = g_{UV}^{-1}\mathbf{\Omega}_U g_{UV} \tag{3}$$

Therefore, under the cross-section transformation $\boldsymbol{\sigma}$, there is $\boldsymbol{\omega}_U \to \boldsymbol{\omega}_V$ on the bottom manifold (that is, the world we assume), namely, Equation (1) holds, and here g_{UV}^{-1} and g_{UV} are related to a gauge transformation.

Furthermore, it can be proven that Equation (3) is equivalent to the following "similarity" transformation Equation (4) [19]:

$$\mathbf{\Omega}_V = g_{UV}^{-1}\mathbf{\Omega}_U g_{UV} \Leftrightarrow \hat{F}'_{\mu\nu} = W\hat{F}_{\mu\nu}W^{-1} \tag{4}$$

where $\hat{F}'_{\mu\nu}$ is defined as the gravitational gauge field strength on the V region of the bottom manifold; $\hat{F}_{\mu\nu}$ is defined as the gravitational gauge field strength on the U region of the bottom manifold. W^{-1} or W can be regarded as the matrix expression of some kind of gauge transformation. The author suggests calling it as the gauge similarity transformation.

We should emphasize that this gauge similarity transformation is influenced by regional scale, or rather depends on changes in regional scale. The scale of U or V in different regions determines different gauge potentials or field strengths. The generalized gauge equation or the gauge similarity transformation above refers to the transformation relationship between the gauge potentials or field strengths of two different regions at the same spatiotemporal point in the bottom manifold (our universe). Moreover, after careful consideration, the author also believes that if the structure group is a general linear group ($GL(m,\mathbb{C})$), the generalized gauge transformation over basic interactions should corresponds to the gauge transformations between several subgroups (such as $U(1)$, $SU(2)$, $SU(3)$, $O(1, 3)$), while the gauge transformation within a basic interaction (such as electromagnetic force) only corresponds to gauge transformations within a subgroup (such as $U(1)$ or $SU(2)$). These components are just a "representation" of the original connection or curvature on the principal bundle in the real world (bottom manifold); in this sense, "quantization" or "classicalization" is just a natural "picture representation" of the original connection or curvature selection in different regions of the real world, and cannot be replaced by each other, or not every physical field can or needs be quantized, especially gravity. It should be emphasized that the original connection (gauge potential) or curvature (gauge field strength) on the principal bundle is gauge invariant, while the gauge potential or field strength on the bottom manifold is only the projection component mapped (gauge selection) from different cross-sections of the original connection or curvature of the principal bundle, which is the physical meaning of the unity of the "four" basic interactions in the world [17] [18] [19].

3. The Physical Essence of Dark Matter and Dark Energy

Based on the above assumptions, this paper believes that dark matter and dark energy are both fictitious hypotheses generated by the differences in the gauge transformation of the gravitational gauge potential or gauge field strength between different regional scales on the bottom manifold. There is no dark matter or dark energy, but only changes in the bottom manifold relative to the original gauge potential or field strength caused by gauge transformation. The original Einstein's equation or Newton's second law may change its form under such a transformation, and may be different from the form before the transformation, and there is a difference, so this difference is blurred into the existence of some kind of dark matter or dark energy.

The specific mathematical and physical foundations and related gauge transformation that make our "theory" valid are constructed as follows:

$$\begin{array}{ccc} \hat{F}'_{\mu\nu} & = & W\hat{F}_{\mu\nu}W^{-1} \\ \hat{F}'_{\mu\nu} \equiv \text{Gauge field strength in } V & \leftarrow & \hat{F}_{\mu\nu} \equiv \text{Gauge field strength in } U \\ & \downarrow\downarrow & \\ & \hat{F}'_{\mu\nu} = \gamma\left(\frac{|a|}{a_0}\right)\hat{F}_{\mu\nu} & \end{array} \tag{5}$$

where, $\gamma\left(\frac{|a|}{a_0}\right)$ can be defined as a function of $\frac{|a|}{a_0}$. The author suggests that it can be called the gauge similarity transformation factor, where $|a|$ is the absolute value of acceleration related to the region and can be defined as the acceleration of a particle relative to a basic framework determined by distant matter in the universe. a_0 is an acceleration constant related to our galaxy, and experiments [10] have found that is approximately $a_0 \sim cH_0 = 2\times10^{-8}\,\text{cm}\cdot\text{s}^{-2} \sim 5\times10^{-8}\,\text{cm}\cdot\text{s}^{-2}$. What is very surprising is that a_0 is very consistent with the measured value of the acceleration of the solar system in the gravitational field of the Milky Way $(2.32 \pm 0.16) \times 10^{-8}\,\text{cms}^{-2}$ [21], indicating that the regional scale corresponding to a_0 is just the scale of our solar system! Therefore, the solar system can be used as a reference system to judge the applicable scope of relativity and Newtonian mechanics. Generally speaking, as the scale of the region corresponding to a_0 increases, it should be more difficult for the regional matter as a whole to change acceleration $|a|$ under the gravitational field of galaxy. Therefore, on average, if the acceleration a_0 as the benchmark, then the larger the scale of the galaxy, the smaller its overall acceleration $|a|$ should be. For example, if a_0 is set as the benchmark, the corresponding solar system region scale is U_{sun}, and the galaxy is V_{uni}, there should be an inverse relationship,

$$\frac{|a|}{a_0} \sim \frac{U_{sun}}{V_{uni}} \tag{6}$$

Obviously, when the galaxy scale V_{uni} tends to the universe scale, the above equation tends to 0. If the galaxy scale shrinks to the U_{sun} scale, the above equation becomes to 1. When the galaxy scale is much smaller than the base system scale, the above equation tends to ∞. The corresponding acceleration shows: when $|a| \ll a_0$, $\gamma\left(\frac{|a|}{a_0}\right) \to \frac{|a|}{a_0} \to 0$, and when $|a| = a_0$, $\gamma\left(\frac{|a|}{a_0}\right) \to \gamma(1)$, while when $|a| \gg a_0$, $\gamma\left(\frac{|a|}{a_0}\right) \to 1$, so the gauge similarity transformation factor γ changes between 0 and 1. In order to reflect this law, we speculatively choose the $\gamma\left(\frac{|a|}{a_0}\right) \equiv th\left(\frac{|a|}{a_0}\right)$ function to "simulate" this change. But this does not take into account the fact that Einstein's law of gravity and Newton's second law normally hold true within the scale of the solar system. Therefore, the author generally believes that when $|a| \ge a_0$, there should be $th\left(\beta\frac{|a|}{a_0}\right) \to 1$. At this time, the reference system should include the scale of our solar system, and an appropriate coefficient β should be introduced, so that when $|a| \ge a_0$,

$$th\left(\beta\frac{|a|}{a_0}\right) \to 1 \tag{7}$$

To ensure that within the scale of the solar system, Einstein's law of gravitational attraction remains unchanged and Newton's law of gravity (second law) remains unchanged, the gauge similarity transformation should be given by

$$\hat{F}'_{\mu\nu} = \hat{F}_{\mu\nu} \tag{8}$$

In other cases, such as $|a| < a_0$, then $0 < th\left(\beta\frac{|a|}{a_0}\right) < 1$, one gets

$$\hat{F}'_{\mu\nu} = th\left(\beta\frac{|a|}{a_0}\right)\hat{F}_{\mu\nu} < \hat{F}_{\mu\nu} \tag{9}$$

At this point, from the perspective of our solar system, Newton's Second Law becomes

$$mth\left(\beta\frac{|a|}{a_0}\right)\boldsymbol{a} < m\boldsymbol{a} = \boldsymbol{F} \tag{10}$$

Newton's Second Law no longer seems to hold true, which is consistent with MOND's viewpoint [21] [22] [23].

In fact, from the perspective that the strength of the gauge field is the curvature of the bottom manifold, considering the Newton approximation, the linear Einstein equation can give [24] [25],

$$m\frac{\mathrm{d}^2 x^i}{\left(\mathrm{d}x^0\right)^2} = -m\Gamma^i_{00} \tag{11}$$

where, Γ^i_{00} is the Christoffel symbols, which is approximated by Newton's condition, $g_{ab} = \eta_{ab} + h_{ab}$, etc., can be transformed into

$$\Gamma^{i}_{00} = \frac{1}{2}\eta^{i\mu}\left(h_{\mu 0,0} + h_{\mu 0,0} - h_{00,\mu}\right) = \frac{1}{2}h_{00,i} \tag{12}$$

Hence one can obtain

$$m\frac{\mathrm{d}^2 x^i}{\left(\mathrm{d}x^0\right)^2} = -m\frac{1}{2}h_{00,i} \tag{13}$$

Further consideration of Newton's second law in the classical field of universal gravitation can be written as

$$m_I \frac{\mathrm{d}^2 x^i}{\mathrm{d}t^2} = m_g\left(-\frac{\partial \varphi}{\partial x^i}\right) \tag{14}$$

where φ is Newton's gravitational potential. Comparing the above two formulas one gets:

$$\varphi = \frac{1}{2}h_{00} + \text{const} \tag{15}$$

Assume that the gravitational field disappears at infinity as $\varphi = 0$, then the metric should return to the Minkowski metric at this time, $h_{00} = 0$, so that the constant in the above formula is 0, which gives

$$g_{00} = -1 + h_{00} = -\left(1 + \frac{2\varphi}{c^2}\right) \tag{16}$$

But considering gauge transformation and Newton approximation one can have

$$\hat{F}_{\mu\nu} \to \gamma \hat{F}_{\mu\nu} \to \gamma \hat{F}_{\mu\nu} \to \gamma \Gamma^{i}_{00} \to \gamma g_{00} \to \gamma h_{00} \to \gamma\varphi \tag{17}$$

Therefore, Newton's second law in the above classical gravitational field becomes

$$m\left(-\frac{\partial \gamma\varphi}{\partial x^i}\right) = m\gamma \boldsymbol{a} < m\boldsymbol{a} = \boldsymbol{F} \tag{18}$$

This difference in gravitation is the origin of the dark matter hypothesis.

In addition, if $V_{uni} \gg$ base system scale, or $\gg$ galaxy scale, then $\frac{|a|}{a_0} \ll 1$, $th\left(\beta\frac{|a|}{a_0}\right) \to 0$, its physical meaning is that the gravitational gauge field strength is $\hat{F}'_{\mu\nu} = th\left(\beta\frac{|a|}{a_0}\right)\hat{F}_{\mu\nu} \to 0$, which corresponds to the zero gravitational gauge field strength of the manifold region on the cosmic scale. So that Equation (18) means that Newton's second law becomes:

$$\lim_{\frac{|a|}{a_0} \to 0}\left[mth\left(\beta\frac{|a|}{a_0}\right)\boldsymbol{a}\right] \to 0 \tag{19}$$

This reveals that the curvature of the entire region at the scale of the universe is 0, and the attraction disappears. The author speculates that at this scale, the universe may be driven by the energy converted from the initial kinetic energy of the original big bang and the disappearing attraction to accelerate expansion, and producing repulsive forces are also possible. This part of the conversion energy from the disappearance of gravity plus the initial kinetic energy left behind by the Big Bang of the original universe may be the origin of dark energy, thus forming a structure of regional distribution of large-scale basic interactions, that is

$$\begin{cases} th\left(\beta\frac{|a|}{a_0}\right)\to 1 & \Rightarrow \text{Newton's second law holds}\left(\text{such as our solar system}\right) \\ 0<th\left(\beta\frac{|a|}{a_0}\right)<1 & \Rightarrow \text{Dark matter}\left(\text{"region"}\geq\text{galaxy}\right) \\ th\left(\beta\frac{|a|}{a_0}\right)\to 0 & \Rightarrow \text{Dark energy}\left(\text{such as the universe currently measured}\right) \end{cases} \tag{20}$$

Furthermore, the above picture is just a branch of the evolution of the universe if considering original $\hat{F}_{\mu\nu}$ as a unit (such as the gauge field strength of the solar system). In the process of $th\left(\beta\frac{|a|}{a_0}\right)$ causing the curvature of the universe to become 0, as the gravitational gauge field of attraction disappears, its energy may be converted into repulsive force, that is $\hat{F}'_{\mu\nu}=th\left(\beta\frac{|a|}{a_0}\right)\hat{F}_{\mu\nu}\to 0^-$ may tend to be negative, causing the curvature to become negative, gradually increasing the repulsive force, and in driven by the initial kinetic energy of the Big Bang, the universe may continue to develop in the direction of negative curvature and accelerate its expansion (this is consistent with the current measurement evidence that extragalactic galaxies are accelerating red shifts [26] [27] [28] [29]), thus evolving into another branch, namely universe with negative curvature:

$$\begin{cases} th\left(\beta\frac{|a|}{a_0}\right)\to -1 & \Rightarrow \text{Applicable regions of Newton's second law} \\ -1<th\left(\beta\frac{|a|}{a_0}\right)<0 & \Rightarrow \text{"Dark matter" region} \\ th\left(\beta\frac{|a|}{a_0}\right)\to 0 & \Rightarrow \text{"Dark energy" universe} \end{cases} \tag{21}$$

where a negative value is taken by β.

Which branch is the universe currently on? Obviously, the gravity in areas smaller than the scale of the universe are still dominated by attraction, that is, the gauge similarity factor is $0<th\left(\beta\frac{|a|}{a_0}\right)<1$, so the universe is in the first branch. However, it is not impossible for the universe to evolve to a second branch in the distant future. The measurement evidence that extragalactic galaxies are generally accelerating their red shifts is a possible interpretation of the negative gauge similarity transformation of the curvature of the bottom manifold (*i.e.* our universe).

Then the universe will continue to oscillate and develop, oscillating back and forth among the curvature of −1, 0, and 1… see the hyperbolic tangent curve shown in **Figure 1**. The hypotheses of these two branches can obtain some support from the solutions of the Friedmann equation, that is, the curvature of the universe evolves possible three scenarios are 0, 1 and −1, which also have similar cyclic characteristics to Penrose's model of conformal cyclic cosmology [17] [25] [30] [31] [32] [33]. The evolution of the universe may be oscillation, cycle, and development among three curvature images of −1, 0, and 1.

But the author needs to emphasize that $\gamma\left(\frac{|a|}{a_0}\right) \equiv th\left(\beta\frac{|a|}{a_0}\right)$ is just a speculation, and whether it is correct or not depends on experiments and observations. The more confident one is still the setting: $\gamma\left(\frac{|a|}{a_0}\right)$ is just certain function of $\frac{|a|}{a_0}$ which satisfies the following graph:

$$\begin{cases} \gamma\left(\frac{|a|}{a_0}\right) \to 1 & \Rightarrow \text{For } |a| \gg a_0, \text{ Newton's second law holds (i.e. solar system)} \\ 0 < \gamma\left(\frac{|a|}{a_0}\right) < 1 & \Rightarrow v(r) = \sqrt{\frac{GM}{\gamma r}} > \sqrt{\frac{GM}{r}} \text{ ("Dark matter" regions} \geq \text{galaxies)} \\ \gamma\left(\frac{|a|}{a_0}\right) \to \frac{|a|}{a_0} \to 0 & \Rightarrow \text{For } |a| \ll a_0, \text{ Dark energy (accelerated expansion of the universe)} \end{cases} \tag{22}$$

where if $v(r)$ is the rotation curve of the galaxy, *i.e.* $\sqrt{\frac{GM}{\gamma r}}$, then after being

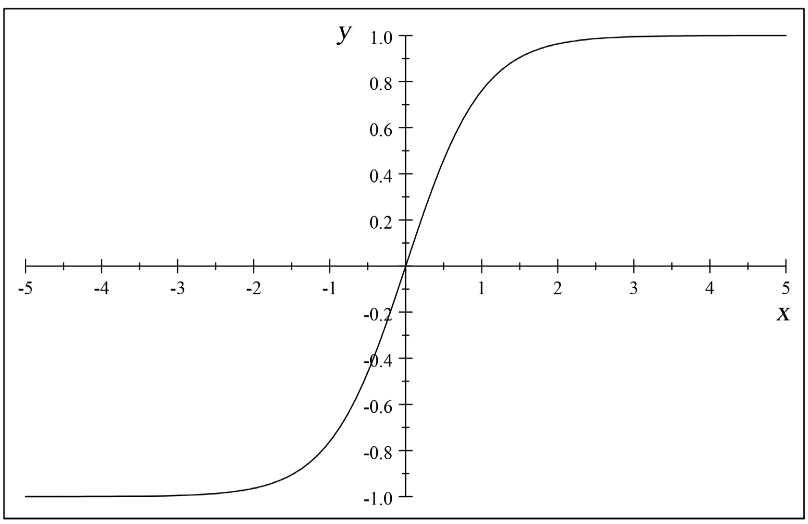

Figure 1. One possible oscillation or evolution of our universe in two branches: $y = th(x)$, $x = \frac{|a|}{a_0}$; $|a| \gg a_0$, $y \to \pm 1$; $|a| \ll a_0$, $y \to 0$; Other, $0 < y < 1$, or $-1 < y < 0$.

account by $0<\gamma\left(\frac{|a|}{a_0}\right)<1$ in the denominator, as r increases, the observation result is greater than the original $\sqrt{\frac{GM}{r}}$, which well explains no existence of "dark matter" and is consistent with the observation and calculation results of MOND [21] [22] [23]. While for the "dark energy", the following two sections can give more clear analysis.

4. Connection or Curvature Determines the Equation of Motion

In the previous analysis and discussion, we can draw an important conclusion: that is, the connection or curvature of large-scale space-time in the universe affects the evolutionary landscape of the universe. Here, the author briefly discusses the kinematic equations related to the large-scale structure of universe:

An important idea in the theory of principal bundles is the connection of principal bundle $\tilde{\boldsymbol{\omega}}$ can induce a derivative operator ∇ on the bottom manifold, and this principal bundle is just the frame bundle *FM*, that is

$$(M,\nabla)\leftrightarrow(FM,\tilde{\boldsymbol{\omega}}) \tag{23}$$

Fortunately, the principal bundle in our universe's diagram is just the frame bundle, so the connection of this frame bundle will have a derivative operator effect on the gauge field in the corresponding region of the bottom manifold, which displays certain geometric kinematic features. Let the cross-section of the constructed associated bundle be $\hat{\boldsymbol{\sigma}}$ representing a physical gauge field, the kinematic equation of this physical gauge field in this cosmic scale region can be determined by obtaining its covariant derivative (see [17]):

$$\nabla_T\hat{\boldsymbol{\sigma}}=\boldsymbol{\sigma}(0)\cdot\left\{\left.\frac{\mathrm{d}}{\mathrm{d}t}\right|_{t=0}f(t)+\left[\rho_*(\boldsymbol{\omega}(T))\right]f(0)\right\} \tag{24}$$

where, $f(t)$ and $f(0)$ are arrays composed by the components of a certain gauge field tensor, $\rho_*(\boldsymbol{\omega}(T))$ is a square matrix, T is a tangent vector in the base manifold, $\boldsymbol{\omega}$ is the connection on the bottom manifold. Therefore the equation of motion is determined by the following equation:

$$\begin{cases}\nabla_T\hat{\boldsymbol{\sigma}}=0\rightarrow\text{Geodesic equation}\\ \nabla_T\hat{\boldsymbol{\sigma}}\neq0\rightarrow\text{Equations of motion driven by connections}\end{cases} \tag{25}$$

For example, if the principal bundle $P=FM$ and the tangent bundle is the associated bundle $Q=TM$, then the associated bundle cross-section $\hat{\boldsymbol{\sigma}}:U\rightarrow Q$ is the tangent field, and let a coordinate system in the bottom manifold region U be $\{x^\mu\}$, utilizing auxiliary cross-sections $\boldsymbol{\sigma}:U\rightarrow P$, then it can be calculated as

$$T^b\nabla_b v^a=T^\sigma\left[\left(\frac{\partial}{\partial x^\mu}\right)^a\left(\frac{\partial v^\mu}{\partial x^\sigma}+\omega^\mu_{\nu\sigma}v^\nu\right)\right]_{x_0} \tag{26}$$

where $\forall x_0 \in U$, T is a vector along point x_0, v^a represents the vector field corresponding to $\hat{\boldsymbol{\sigma}}$, and $\nabla_T \hat{\boldsymbol{\sigma}} = T^b \nabla_b v^a$. For example, if taking $v^\mu = T^\mu = \frac{\mathrm{d}x^\mu}{\mathrm{d}t}$, $T^\sigma \frac{\partial v^\mu}{\partial x^\sigma} = \frac{\mathrm{d}v^\mu}{\mathrm{d}t}$, then the equation of motion can be:

$$T^b \nabla_b T^a = 0 \to \frac{\mathrm{d}T^\mu}{\mathrm{d}t} + \omega^\mu_{\nu\sigma} T^\sigma T^\nu = 0 \tag{27}$$

The geodesic equation is thus obtained:

$$\frac{\mathrm{d}^2 x^\mu}{\mathrm{d}t^2} + \Gamma^\mu_{\nu\sigma} \frac{\mathrm{d}x^\nu}{\mathrm{d}t} \frac{\mathrm{d}x^\sigma}{\mathrm{d}t} = 0 \tag{28}$$

In addition, considering Equation (25), it can be determined that Equation (26) is the general equation of kinematics of the frame bundle contact action gauge vector field. At this point view, the frame bundle connection is a derivative operator on the bottom manifold, and the associated bundle cross-section is a physical field, and the effect of the connection on the physical field is to obtain covariant derivatives of the physical field. When this physical field is a tangent vector and the direction is consistent with the derivative operator, the covariant derivative of the tangent vector is 0, and then the equation of motion becomes a geodesic equation.

5. The Secret of the Universal Term in Einstein's Equation

The connections or curvature of large-scale space-time can certainly affect the dynamical equations. In fact, the physical essence reflected in the gauge similarity transformation Formula (4) can be realized by introducing a factor that changes with space-time scale in the universal term of Einstein's equation, for example

$$G_{ab} + \Lambda\left(\frac{|a|}{a_0}\right) g_{ab} = 8\pi T_{ab} \tag{29}$$

where G_{ab} is the Einstein tensor, g_{ab} is the metric tensor, T_{ab} is the energy and momentum tensor, Λ is originally the cosmological constant, and now it is related to $\gamma\left(\frac{|a|}{a_0}\right)$, that is

$$-\Lambda g_{ab} = 8\pi\left(\frac{1-\gamma}{\gamma}\right) T_{ab} \tag{30}$$

Proof: From the gauge similarity transformation and Einstein's equation, let $\gamma = th\left(\beta \frac{|a|}{a_0}\right)$, we have

$$\gamma R_{ab} - \frac{1}{2}\gamma R g_{ab} = 8\pi T_{ab} \tag{31}$$

So we can get

$$R_{ab} - \frac{1}{2} R g_{ab} = \frac{8\pi}{\gamma} T_{ab} \tag{32}$$

Consider again Einstein's equation with the cosmological constant Λ

$$R_{ab}-\frac{1}{2}Rg_{ab}+\Lambda g_{ab}=8\pi T_{ab} \tag{33}$$

And because the above equation can become

$$8\pi T_a^a=R_a^a-\frac{1}{2}\delta_a^a R+\delta_a^a\Lambda=R-2R+4\Lambda=-R+4\Lambda$$

namely

$$R=-8\pi T+4\Lambda \tag{34}$$

So (33) can be reduced to

$$\begin{aligned} R_{ab}&=8\pi T_{ab}+\frac{1}{2}Rg_{ab}-\Lambda g_{ab}\\ &=8\pi T_{ab}+\frac{1}{2}(-8\pi T+4\Lambda)g_{ab}-\Lambda g_{ab}\\ &=8\pi\left(T_{ab}-\frac{1}{2}Tg_{ab}\right)+\Lambda g_{ab}\end{aligned} \tag{35}$$

Then bring Equation (34) and (35) into Equation (32), we get

$$\begin{aligned} \frac{8\pi}{\gamma}T_{ab}&=R_{ab}-\frac{1}{2}Rg_{ab}\\ &=8\pi\left(T_{ab}-\frac{1}{2}Tg_{ab}\right)+\Lambda g_{ab}-\frac{1}{2}(-8\pi T+4\Lambda)g_{ab}\\ &=8\pi T_{ab}-\Lambda g_{ab}\end{aligned} \tag{36}$$

Hence we have Equation (30) established, that is

$$-\Lambda g_{ab}=8\pi\left(\frac{1-\gamma}{\gamma}\right)T_{ab}$$

Under condition (30), Equation (31) can be reduced to

$$\begin{aligned} R_{ab}-\frac{1}{2}Rg_{ab}=\frac{8\pi}{\gamma}T_{ab}&=\frac{8\pi}{\gamma}T_{ab}-\frac{\gamma}{\gamma}8\pi T_{ab}+8\pi T_{ab}\\ &=8\pi\left(\frac{1-\gamma}{\gamma}\right)T_{ab}+8\pi T_{ab}\\ &=-\Lambda g_{ab}+8\pi T_{ab}\end{aligned} \tag{37}$$

So we have the Einstein Equation (33) with the cosmological term.

Therefore, a conclusion can be drawn: when condition (30) is established, the Einstein equation with gauge similarity transformation and the original Einstein equation can be derived from each other, that is, we have

$$\begin{gathered} \gamma R_{ab}-\frac{1}{2}\gamma Rg_{ab}=8\pi T_{ab}\\ \downarrow\uparrow\\ R_{ab}-\frac{1}{2}Rg_{ab}+\Lambda g_{ab}=8\pi T_{ab}\end{gathered} \tag{38}$$

Let me emphasize again that γ is defined here as the gauge similarity transformation factor, Λ is the cosmological constant of Einstein's equation, and the relationship between the both is Equation (30).

So the gauge similarity transformation $R_{ab}\to\gamma R_{ab}$ is equivalent to adding the cosmological constant Λ to Einstein's equations. This shows that in a certain sense, adding a certain cosmological constant to the Einstein equation is equivalent to applying a certain gauge similarity transformation to the curvature. The cosmological constant is no longer a constant, and is related to the coefficient γ of the gauge field strength after the gauge similarity transformation, which is the physical meaning of the cosmological constant. Not only that, Λ is affected by $\gamma\left(\frac{|a|}{a_0}\right)$, Λ is also a function of the space-time scale, that is, it becomes larger as the time-space scale becomes larger; when the time-space scale tends to the cosmic scale, $\gamma\left(\frac{|a|}{a_0}\right) \to \frac{|a|}{a_0} \to 0$, $\Lambda \to -\infty$, the gauge gravitational field strength is 0, and Einstein's equation fails; when the space-time scale is smaller than the scale of the solar system, $\gamma\left(\frac{|a|}{a_0}\right) \to 1$, $\Lambda \to 0$, the gravitational field strength remains unchanged after gauge transformation, the original Einstein equation holds, and Newton's second law holds. The conditions that must be met for the specific change of Λ are determined by Equation (30).

6. The Λ Variable Affects the Einstein Equation

From the above analysis of the Einstein equation's cosmological constant, the author found that since the cosmological constant is now not a constant but a function that varies with the scale of the universe region, or the ratio to regional acceleration $\frac{|a|}{a_0}$ is related, so the Einstein equation will vary with the size of the universe region, and take on different forms. Therefore, the Newton's law or the law of universal gravitation that appears in the U region observed at the same point in the bottom manifold (*i.e.* our universe) may not necessarily be the same as the Newton's law or the law of universal gravitation observed in the V region at the same point. The transformation between them satisfies a gauge similarity transformation (or generalized gauge equation); and it is precisely the difference between the both to cause the virtual origin of hypothesis for the dark matter and the dark energy.

In fact, from Equation (36), the Einstein equation containing the cosmological term becomes

$$R_{ab} - \frac{1}{2} R g_{ab} = 8\pi T_{ab} - \Lambda g_{ab} = 8\pi \frac{T_{ab}}{\gamma\left(\frac{|a|}{a_0}\right)} \tag{39}$$

namely

$$G_{ab} = 8\pi \frac{T_{ab}}{\gamma\left(\frac{|a|}{a_0}\right)} \tag{40}$$

Here G_{ab} certainly is the Einstein tensor. Therefore, the large-scale Einstein equation of the universe is suggested to be given by the following formula:

$$G_{ab} = R_{ab} - \frac{1}{2} R g_{ab} + \Lambda\left(\frac{|a|}{a_0}\right) g_{ab} = 8\pi T_{ab} \tag{41}$$

Therefore, the evolution law of Einstein's equation in the large-scale universe is affected by $\Lambda\left(\frac{|a|}{a_0}\right)$ or $\gamma\left(\frac{|a|}{a_0}\right)$ and is expressed as follows:

$$\begin{cases} G_{ab} = 8\pi T_{ab}, |a| \gg a_0, \gamma \to 1, (\text{The area where Einstein equation and Newton gravity hold}) \\ G_{ab} = 8\pi \frac{T_{ab}}{\gamma}, 0 < \gamma < 1, (\text{dark matter, Einstein's equation and Newton gravity deviation area}) \\ -\Lambda g_{ab} = 8\pi\left(\frac{1-\gamma}{\gamma}\right) T_{ab} \to \infty, |a| \ll a_0, \gamma \to 0, (\text{A chaotic region where gravity disappears} \\ \qquad \text{or repulsive force appears}) \end{cases} \tag{42}$$

In terms of details, the relevant mechanism of the two limit points with curvature 0 and 1 in the above picture can also be explained as follows:

The interval with a curvature of 0 is the fluctuation or chaos region where all gravitational or repulsive forces disappear or begin to occur. At the limit point of 0, neither Einstein's equation nor Newton's second law completely holds. The repulsive energy converted from the disappearance of gravity is the source of dark energy. So "the problem of cosmological constant for physicists" has not existed [17].

Whether the universe ultimately continues to evolve depends on which part of the force disappears much more. Obviously, from the first branch to point 0, gravity disappears much more, so repulsive forces will inevitably occur much more, and the universe will evolve towards the second branch. On the contrary, there is a high probability that universe will evolve towards the first branch. It is not impossible for the universe to oscillate and evolve repeatedly in a branch with a certain probability. In the process of the curvature of the first branch of the universe tending towards 1, as $|a| \gg a_0$, and the simultaneous surface gradually tend to a closed 3-dimensional circular sphere, with its spatiotemporal scale compressed until it becomes a singularity, and then the Big Bang begins a new curvature evolution from 1 to 0; in the second branch, the author speculates that as the curvature of the universe tends towards −1, the simultaneous surface of the universe presents a continuously compressed and reduced 3-dimensional saddle surface under the constraint that its overall energy must be conserved, until the time-space becomes a singularity, and then the kinetic energy of the Big Bang drives the evolution of its curvature from −1 to 0. At the +1 limit point, both the Einstein equation and Newton's second law hold. At the −1 limit point, the Einstein equation and Newton's second law require sign changes. But it is still unclear whether that is a world dominated by "universal repulsion"…

In the first branch: $0 < \gamma < 1$, or second branch: $-1 < \gamma < 0$ compared with the Einstein equation and Newton's second law of the solar system, both the Einstein equation and the Newton's second law are partially valid. The difference between those is just the source of dark matter hypothesis.

7. Conclusions and Outlook

In this paper, the author proposes a hypothesis about the structure of large-scale gravitational interactions in the universe and the oscillatory evolution of the universe with a hyperbolic tangent function. These hypotheses are based on the theory of principal bundles and gauge similarity transformations. The author believes that our universe is a bottom manifold under the principal bundle, and the laws of cosmic evolution are hidden in the principal bundle above the bottom manifold. The structure group and relevant gauge transformations provide a similarity transformation of the gauge field, which can reflect the connection between the strength of the physical gauge field and the large space-time scale of the universe, as well as the mutual relationship between the gauge field strengths in the two different space-time regions. The results obtained are unexpected:

1) The unified understanding of the hypothesis of dark matter and dark energy is caused by data biases between the measured massive galaxy system and solar system from the calculations of the Einstein equation or Newton's second law. Actual dark matter, dark energy does not exist!

2) The Einstein equation and Newton's second law can only be partially true for these massive galaxies. Its correction can be given by the cosmological constant term of the Einstein equation. But this cosmic constant actually varies with the size of the universe and is related to the gauge similarity transformation factor. The overall acceleration of the "solar system" a_0 can be selected as benchmark, which is 2.5×10^{-8} cm/s^2; then the cosmological constant Λ varies with the absolute value $|a|$ of the overall acceleration of the large-scale cosmological structure by comparing to a_0, *i.e.* $\Lambda\left(\frac{|a|}{a_0}\right)$.

3) If the gauge field strength of the datum system is defined as the unit, then the universe oscillates and evolves according to the function type of the gauge similarity transformation factor $\gamma\left(\frac{|a|}{a_0}\right)$, which can be divided into two branches, *i.e.* $0 \le \gamma\left(\frac{|a|}{a_0}\right) \le 1$ and $-1 \le \gamma\left(\frac{|a|}{a_0}\right) \le 0$. The corresponding curvatures are 1, 0, −1, and the universe oscillates and develops among these curvatures of 1, 0, and −1. A curvature of ±1 corresponds to the two singularities before the Big Bang, and a curvature of 0 corresponds to the chaotic region where gravity and repulsion disappear or arise.

4) The above results have covered almost all the most important difficult issues on basic interaction theory and cosmology in current theoretical physics, and the progresses are obvious. They once again illustrate that the principal bundle picture about the evolution of universe [18] [19] based on the principal and associated bundles of differential geometry and the generalized gauge transformation or the gauge similarity transformation may be a very important founda-

tion and starting point for studying the basic interaction structure of large-scale gravity in the universe, and are expected to shine in future research on cosmology.

Conflicts of Interest

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

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