New Principle of Dynamical Relativity and Space-time Physical Picture

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In this article, we systematically present a novel physical picture of space-time. Firstly, we reinvestigate the problem of dynamical relativity from the viewpoint of causality principle. We suppose that the counting of forces should also be relative so that it can be consistent with the relative description of kinematical quantities. Further we propose a new axiom for dynamical equation—the principle of causality consistency. Then we carry out a subtle way to realize a universal dynamical relativity, in which the dynamical equation can be exactly applied in any reference frame and the essence of inertial force can also be naturally explained. After that a new physical picture for space-time in accordance with the new principle of relativity is drawn as follows. All reference frames are equivalent on the description of kinematics and their proper clocks run at the same rate. Secondly, according to the new principle of relativity, the geometrized effect of gravity should be regarded as a non-Minkowski metric based on a rigid homogeneous reference coordinate system. The gravitational time dilation exists in any local clock in gravity field, regardless of its state of motion. And all the local space-time are of asymptotic Minkowski metric. Following this way, we successfully reinterpreted the gravitational redshift in the solar system. Besides, we also reinvestigated the foundation of cosmology and proposed a new cosmological metric in which the gravitational redshift can be explicitly embodied. A preliminary analysis suggested that if we adopt this new metric in cosmology then current cosmological problems will be expected to be basically resolved.
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1 INTRODUCTION

Historically the ideas about space and time can be divided into two kinds: Absolutism and Relativism. The absolutism hold the view that the measured interval of space and time is absolute and has nothing to do with the change of observers. The concepts of absolute space-time is mainly developed by Galileo, Leibniz and Newton, and which has provided a theoretical foundation that facilitated Newtonian mechanics. In Newtonian mechanics, space and time are independent of each other and there is no relation between them in the measurement. A kinematical quantity for a same object measured in different inertial reference frame can be related to each other by Galileo transformation. Incorporating a presumption that the force is invariant under the transformation of inertial reference frames, then it renders the Galileo principle of relativity that the rules of mechanics must be the same for all inertial observers, regardless of the speed of the frame of reference.

However, since the theory of special relativity is put forward by Einstein at the beginning of the 20th century, it has achieved a great success. In special relativity, both the measured interval of space and time would no longer be absolute, and they are related to the state of motion of the reference frame. The kinematical quantity for a same object observed in different inertial reference frame complies with Lorentz transformation. Accordingly, special relativity presents the special principle of relativity that any physical law keep formal invariant under the Lorentz transformation, or all inertial reference frames are equivalent on the description of physical laws[1]. In fact, the root of all peculiar properties of space-time in special relativity is the principle of constant light speed. Therefore, either the measurement of the space or time interval is relative but the proper clock fixed in any inertial reference frame essentially runs at the same rate.

In general relativity, based on the numerical equality of the gravitational mass and the inertial mass, a principle of equivalence is first introduced by Einstein in 1907. This Einstein equivalence principle states that the outcome of any local non-gravitational experiment in a freely falling laboratory is independent of the velocity of the laboratory and its location in space-time[2]. It means that the proper clock in all the local inertial reference frame run at the same rate, and be equivalent to the clock at rest with null gravity. Resorting to the principle of equivalence, Einstein generalize the dynamical relativity to all reference frames, regardless of their state of motion. In general relativity, the curvature of the space-time is determined by the distribution of the matter field[3–6]. In addition, the gravitational redshift effect has been proved by a series gravity tests in the solar system. This effect has adequately illustrated that geometry is more accurate than Newton's law to describe the gravity. Nonetheless, the conventional theory of gravity remains to be confronted with a further in-depth inspection on its fundamental concepts. In fact, It immediately generates stein challenge once the conventional theory of gravity is applied into the cosmology.

As an alternative theory of gravity, general relativity was applied into the study of the universe shortly after Einstein established his general relativity in 1915, thus initiated the beginning of modern cosmology. Up to now, the cosmology has developed into a subject of precise science incorporating the observation of supernova, cosmic microwave background and so on[7, 8]. However, the standard cosmology is currently confronted with some rigorous challenges, such as dark energy[9], dark matter[10]. Especially dark energy, it may fundamentally change the scientific research orientation. Therefore, considering the essential characteristic of cosmology that the dynamics of the universe can not be repeatable by experiments, we should hold a more objective and open mind and pay more attentions to scrutinise the foundation of the cosmology.

In this article, we reinvestigate the realization of the general principle of relativity and propose a new physical picture of space-time. It can self-consistently explain the gravitational redshift effect in the solar system. Furthermore, we also introduce a new cosmological metric which is expected to basically solve the current cosmological problems.

2 CAUSALITY CONSISTENCY PRINCIPLE AND DYNAMICAL RELATIVITY

2.1 space-time background and relativity of kinematics

In this section, we will reconsider the problem of relativity of dynamics. In light of the success of special relativity in modern physics, the starting-point of our investigation is the essential characteristic of space-time in special relativity.

As well known, in special relativity, there exists relativity of the simultaneity and "twin paradox" in which the time dilation is relative to each other. The physical picture in coincidence with all fundamental properties in special relativity is that all inertial reference frames are equivalent on the description of kinematics, and the proper clock located in these reference frames run at the same rate. To understand this point, we may introduce here a new concept—"space-time background", which should be distinguished from Newton's absolute space-time. Here space-time background is defined just as the state of the universe after we remove all the movable objects in the universe. Therefore, in space-time background there should be without any natural reference object and without any proper scale. For a single object we are not able to measure the purely objective state of motion because there is no natural reference frame in the space-time background can be resorted. It infers that it is impossible to determine a particular value of velocity because there is no particular reference frame. And all reference frames moving in uniform motion with respect to each other are equivalent on the description of kinematics.

On the other hand, if we set the equivalency of all inertial reference frames to be a fundamental principle in kinematics, then the speed of light propagating in the vacuum is certainly to be constant and invariant under the transformation of reference frames. Since the light propagates through not a medium, but by means of self-excited electro-magnetic field, without a particular reference frame get involved. This point is different from the conventional mechanical waves. Takeing the example of sound waves, the propagation of sound waves depends on air meanwhile the speed of air depends on a material reference frame. Hence a mechanical wave will propagate at different speeds in different reference frames. Therefore, we may suppose that the principle of constant light speed is the inevitable requirement of the essential equivalency in kinematics among all inertial reference frames.

Following this way, we may further propose a conjecture that the acceleration of a reference frame is also relative due to the empty of space-time background. And all reference frames moving in accelerated motion with respect to each other are equivalent on the description of kinematics. If this proposal is verified, then any measurement of the motion of the object is relative, and all reference frames are equivalent on the description of kinematics, or in equal status. In the same comprehension, we may also postulate that the principle of constant light speed will be maintained to any observer and any reference frame.

2.2 dynamical relativity and the condition of causality consistency

Physical law is always embodying the principle of causality. For example, as far as dynamical equation is concerned, forces exerted on an object can be regarded as *cause* and state of motion of the object is regarded as $effect$. The consistency on cause and effect just means the motion is only caused by the counted forces. In general, the equivalency on kinematics among all reference frames will not inevitably lead to the equivalency on dynamics. Then how to carry out a relativity for dynamics laws, which should be invariant under the transformation between different reference frames? A most natural approach is to keep the causality consistency on the counting of forces(*cause*) and the measurement of motion($effect$) in the dynamical equation. Here this approach is named as a $condition\ of\ consistency$ *on cause and* $effect$ for dynamical equations.

The first meaning of this condition is that to maintain the validity of the dynamical equation, the counting of forces must be correspondingly relative, since the description (or measurement) of motion for an object must be relative.

In reality, the observation of physical phenomena is always limited in a local region. Theoretically we need to count all forces exerted on the particle according to Newtonian mechanics. In fact, we are only able to count the forces exerted by the objects located inside the observable region, and fail to count the interaction from the outside of the observable region. Thus the actually counted forces can only be relative. The second meaning of the condition is that the relative counting must be consistent with the relative measurement of motion. How to implement such a causality consistency condition on the measurement (or counting) of kinematical quantities and interactional quantities? We can assume that we have defined a reference origin, then the counting of forces in principle should be limited to the surplus part of forces. It equals the forces exerted on the particle subtracting the force exerted on another particle which is comovingly located at the reference origin and has the same mass. Such a relative counting for interactional quantities would meet the condition of consistency on cause and effect.

2.3 causality consistency principle and dynamical relativity

Practically, if we apply the condition of consistency on cause and effect to the dynamics on the level of natural philosophy, a formalized dynamical identity, which can be exactly applied in any reference frame, can be directly derived. It will show that the dynamical relativity with the condition of consistency on cause and effect is essentially equivalent to making such a fundamental hypothesis, named as *the principle of causality consistency*, that the fundamental dynamics law is linear, and the *objective* motion and the *objective* force for any particle must keep causality consistency in the law. Here *objective* just means the objective property which is inherent to the state of motion and not related to the concrete reference frame.

For example, we study the particle dynamics. The principle of causality consistency can be expressed by

$$K_a|_p = \sum_b f_{ab} F_b|_p, \tag{1}$$

here $K_a|_p$ is one kind of purely objective kinematical quantity, and $F_b|_p$ is one kind of purely objective interaction exerted on the particle p and f_{ab} is the parameter which may be dependent upon intrinsic properties of the particle. In similar, for any arbitrary moving point O which we would like to select as a reference point, we always can imagine that there is another particle (with the same of f_{ab} of p) located on the position of O and comoving with it. It obeys the same law:

$$K_a|_O = \sum_b f_{ab} F_b|_O. \tag{2}$$

In fact, the purely objective motion of the particle is never able to be measured, and the purely objective force exerted on the particle is never able to be totally counted. The measurement of the motion of the particle must be relative to a subjectively selected reference frame. But in a subtle way, we can achieve an exact relativity for dynamical laws by resorting to the "consistency on cause and effect". As long as we make a subtraction between above two equations (1) and (2), then a universal form of dynamical laws is carried out

$$K_a|_{p-O} \equiv K_a|_p - K_a|_O = \sum_b f_{ab} F_b - \sum_b f_{ab} F_b|_O \equiv \sum_b f_{ab} F_b|_{p-O}. \tag{3}$$

Here $K_a|_{p-O}$ means the kinematical quantity of the particle p measured relative to O, and $F_b|_{p-O}$ means the remnant interaction exerted on the particle p which is counted relative to the case of a same f_{ab} particle comoving with O. For example, if the purely objective acceleration for the particle p is denoted by A (corresponding to $K_a|_p$) which means the objective section of the state of accelerated motion and does not change with the observer. And $\mathbf{a}$ (corresponding to $K_a|_{p-O}$) denotes the vector of acceleration after a reference frame is subjectively selected. As a contrast, a_i denotes the component of the acceleration vector after a coordinate system is further subjectively selected. Usually, the distance between p and O can be measured precisely. Meantime, we can always count the difference of the force in a required precision between these two particles, although we are not able to count the purely objective force exerted on single particle. Therefore, such a realization of dynamical relativity demonstrated in (3) guarantee that the dynamical equation is exactly valid in any reference frame and can also be precisely applied.

To illustrate the physical picture of causality consistency, we take Newtonian mechanics as the example of dynamical laws and cite a simple case, which includes the sun (assumed to be a homogeneous sphere, mass denoted by M_{sun}), the earth (assumed to be a homogeneous sphere, mass denoted by M_{earth})and a massive particle p(mass denoted by m). The position vector in direction from point A to point B is uniformly denoted by $\mathbf{r}_{A-B}$. Now we investigate the dynamics of the particle. In consideration of the mass of the sun being much larger than that of the earth, so for simplicity, we assume the sun is at rest and the earth and the particle are both in the state of motion. If we take the center of the earth as the origin point of reference frame, according to normally understand, the dynamics of particle will not satisfy Newton's second law:

$$m\mathbf{a}_{p-earth} \neq G\frac{M_{sun}\cdot m}{r^3_{p-sun}}\mathbf{r}_{p-sun} + G\frac{M_{earth}\cdot m}{r^3_{p-earth}}\mathbf{r}_{p-earth}. \tag{4}$$

The reason is that the earth centered reference frame is not an exact inertial reference frame when the gravity from the sun is under consideration. However, the sun centered reference frame is still not an exact inertial reference frame when we consider the gravity from the outside of the solar system. The definition of the inertial reference frame is an unsolved issue in classical mechanics, and this point is also one of the motivations for Einstein to put forward the general principle of relativity. The keypoint to solve above problem is that the counting of forces should also be relative. According to the condition of consistency on cause and effect, since the motion of the particle is measured relative to the center of the earth, the counting of the force is actually the remnant force after the force exerted on a same particle placed on the center of the earth and comoving with it ($G\frac{M_{sun}\cdot m}{r^3_{earth-sun}}\mathbf{r}_{earth-sun}$) is subtracted. Therefore, we have the identity as follows,

$$m\mathbf{a}_{p-earth} = [G\frac{M_{sun}\cdot m}{r^3_{p-sun}}\mathbf{r}_{p-sun} - G\frac{M_{sun}\cdot m}{r^3_{earth-sun}}\mathbf{r}_{earth-sun}] + G\frac{M_{earth}\cdot m}{r^3_{p-earth}}\mathbf{r}_{p-earth}. \tag{5}$$

It is easy to check, if we assume to put the particle on the center of the earth, obviously the particle will keep at rest with respect to the center of the earth. Thus on the left side of above equation we have $\mathbf{a}_{p-earth} = 0$. On the right side, since at that time there are $\mathbf{r}_{p-sun} = \mathbf{r}_{earth-sun}$ and $\mathbf{r}_{p-earth} = 0$, we also have zero result. Hence the equation (5) is verified in a special case. In essential, above way to keep the consistency on cause and effect can be generalized to arbitrary particle and arbitrary reference frame. We may assume that the total purely objective force exerted on a particle p is F_p and the reference origin of an arbitrary reference frame is O. At the same time, we place another particle (with the same mass of p) on the origin point O and make it comoving with O. We assume the total purely objective force exerted on this imaginary particle is $F_p|_O$. Then for the arbitrary reference frame(O), the following equation is exactly valid

$$m\mathbf{a}_{p-O} = F_p - F_p|_O, \tag{6}$$

here $\vec{a}_{p-O}$ denotes the vector of acceleration of the particle which is relative to the origin point O. The relative counting of the force is nothing but the following definition:

$$\mathbf{f}_{p-O} \equiv F_p - F_p|_O. \tag{7}$$

Finally, we obtain a universal form in which the dynamical equation is exactly valid in any reference frame

$$m\mathbf{a}_{p-O} = \mathbf{f}_{p-O}. \tag{8}$$

This is just the main spirit of the consistency on cause and effect for dynamical equations addressed as an emphasis in this article. It is also easy to see that the special principle of relativity is consistent with the condition of consistency on cause and effect. And inertial force is essentially the force must be subtracted in the relative counting of forces according to the equation (7-8).

2.4 causality consistent reference frame

For any reference frame, a relative description for kinematical quantities is easily obtained. But the relative counting on the force is not the case. Therefore, theoretically the relativity of physics laws for all reference frames has been carried out as the form (8). But we must learn how the condition of consistency on cause and effect can be broadly satisfied in the application of physics laws, although the dynamical law is exactly valid in any reference frame. Practically, it is useful for us to pick out a class of special reference frames to meet this condition more convenient or more easy to count the forces relatively. More specifically, we hope that the force exerted by all objects outside a finite region can just be wholly counterbalanced in the relative counting of forces by selecting a special reference frame.

For example, if in the earth system we investigate the motion relative to the center of the earth, and the force exerted by all objects outside the earth system can be approximated to be equal when the particle appears at different positions in the earth system, then for gravitational part we only need to count the gravity exerted by the objects inside the earth system, rather than the gravity from other planets. In the same reason, if we are in the solar system, investigate the planets' motion relative to the center of the sun and the gravity from outside the sun is nearly homogeneous, then for gravitational part we just need to count the gravity from the solar system, instead of that from outside the solar system.

Broadly speaking, gravitational interaction is the only one long range interaction in the universe, and the gravity is more accurately described by geometry. Therefore, we can naturally define a class of special reference frame resorting to the gravitational bound systems existing in the universe at variant levels[11]. The center of these gravitational bound system can be identified as the origin point of the reference frame at every level. Henceforth the relative counting of the gravity is limited to the inside region of whole bound system. The dynamical equation can be applied in a controlled precision depending on how we make the approximation to meet the condition of consistency on cause and effect. In fact, such a kind of particular reference frame is naturally distributed around the universe, so it can be named as $natural\ reference\ frame(\ NRF\ )$.

Theoretically, a general NRF must be defined by resorting to the condition of consistency on cause and effect. In considering that the reference origin of the NRF is definitely at rest in the reference frame, the displacement of the origin point relative to itself is zero. Therefore, the reference origin must be selected at the point where the relative counting of the forces is zero. Practically, above approach can be carried out by two steps. The first step is selecting an appropriate region which is observable so as all forces exerted by objects inside the region can be counted exactly. The second step is finding an reference origin point on which the forces are exerted from the whole region is zero.

For example, the gravity from inside the earth system exerted on a particle at the center of the earth is zero, hence the center of the earth is qualified to be the reference origin of a NRF. By such a reference frame, we can study relative motion of any object inside the earth gravitational system. There kinematical quantities are measured with respect to the center of the earth. And the counting of the gravity can be simplified to that from other matter inside the earth system if the difference on the gravity from the outside of the earth system with regarding to the specific position of the particle can be ignored. Following this way, the center of the sun is qualified to be the origin of a bigger NRF when we study the relative motion of objects in the solar system. And the center of a galaxy is qualified to be the origin of another NRF when we study the relative motion of objects inside the galaxy.

2.5 alternative physical picture for space-time

As we know, the gravitational redshift has been measured using clocks on a tower[12],an aircraft[13] and a rocket[14], all verified the gravitational redshift effect in the solar system, currently reaching an accuracy of 7×10^{-5}. On the other hand, the numerical equality of the gravitational mass and the inertial mass is actually sufficient to introduce a geometric equivalence description for the gravity. For example, we illustrate this idea by the trajectory of satellites in the space. To make things simpler we assume the trajectory is a circle. According to Newtonian mechanics, it have

$$\frac{GMm}{r^2} = m\frac{v^2}{r} \Rightarrow v^2 = \frac{GM}{r}. \tag{9}$$

Obviously, the unique trajectory parameter r is independent to the concrete mass of the satellite. That is to say, the dynamical law of the satellite in the gravity field has no direct correlation with the magnitude of gravity exerted on this satellite. Therefore, the dynamical law of the satellite can be equivalently described by a kinematical law. This is just a concrete example that the physical effect of gravity can be geometrized.

After the overall integration of above considerations, we suppose that a self-consistent physical picture for space-time can be drawn as follows. 1, The time dilation caused by a relative speed is also relative to each other; all reference frames are equivalent on the description of kinematics and their proper clocks run at the same rate when in zero gravity. 2, In gravity field, a local clock at rest runs at the same rate with the clock at the same positon in a locally free falling state; The gravitational time dilation exists in all local clocks in gravity field, regardless of their state of motion; All the local space-time are of asymptotic Minkowski metric.

After that, a new physical picture of gravity geometrization is also emerged. We suppose that the geometrized effect of gravity should be regarded as a non-Minkowski metric based on a rigid homogeneous reference frame. After the procedure of geometrization is completed, the coordinate time in the metric is still measured by a mathematical clock which has been introduced in original by the present observer and duplicated at all the space-time points, so it can be considered as a background clock. While the local clock in gravity field, regardless of its state of motion, will show the gravitational time dilation effect. In the current scenario, the curvature of the space-time can be partially reflected by the difference in the speed rate between the local clock and the mathematical clock (corresponding to background clock).

3 REINTERPRETATION OF THE GRAVITATIONAL REDSHIFT IN SOLAR SYSTEM

As for the mathematical form of gravity geometrization, Einstein's gravitational field equation should be firstly considered since it has achieved a quantitative success on the gravity test in the solar system[3, 8]. It is not hard to find that the gravity geometrization in the solar system by Einstein's field equation is in coincidence with the new principle of dynamical relativity. More specifically, in the deduction of Schwarzschild metric, the counting of the gravity is actually limited to the gravity exerted from the inside of the solar system. Meanwhile, the reference origin is also fixed at the center of the solar system. Therefore, what the solar gravity test has essentially satisfied is the dynamical relativity with the condition of consistency on cause and effect.

We reinterpret the gravitational redshift in the solar system to examine the new physical picture for gravity geometrization. We can directly adopt the mathematical form of Schwarzschild metric since the concrete solving process for Schwarzschild metric has nothing to do with the specific meaning of the coordinate time t. The full expression of Schwarzschild metric can be written down as

$$ds^2 = -(1-\frac{2GM}{r})dt^2 + (1-\frac{2GM}{r})^{-1}dr^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2. \tag{10}$$

The coordinate time t in the form (10) is actually measured by a mathematical clock initially introduced before the gravity is geometrized, which runs at a rigid homogeneous rate. Since the gravity field around the sun is in a vacuum spherical symmetry, the metric of space-time is stationary. In other words, $g_{\mu\nu}$ has nothing to do with the time. Now we assume there are two spatial coordinate points. One is $p_1(\vec{r}_1)$. Another is $p_2(\vec{r}_2)$. We introduce a light signal propagates from p_1 to p_2 to investigate the gravitational redshift effect in the solar system. There is a wavefront is emitted at the moment of coordinate time t_1, arrives at p_2 at the moment of coordinate time t_2. Thus the time interval measured by a mathematical clock (background clock) is $\delta t = t_2 - t_1$. Similarly, for the propagation of the next wavefront whose phase difference is 2π, also from p_1 to p_2, the time interval measured by a mathematical clock is $\delta t' = t_2' - t_1'$. Considering that the space-time around the sun is stationary, it will have

$$\delta t = \delta t', \tag{11}$$

which further indicates

$$dt_2 \equiv t_2' - t_2 = t_1' - t_1 \equiv dt_1. \tag{12}$$

Above equation means that a light signal will keep an invariant cycle time and frequency measured by the mathematical clock (background clock) in its propagation to any position in the gravity field.

To two arbitrary events: $(t_1, \vec{r}_1)$ and $(t_2, \vec{r}_2)$, we can define their proper time interval directly from the invariant interval ds in analogy to that of special relativity. It is given by

$$-d\tau^2 = -(1-\frac{2GM}{r})dt^2 + (1-\frac{2GM}{r})^{-1}dr^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2. \tag{13}$$

Therefore, for the light signal emitted two wavefronts from p_1 at the moment of t_1 and t_2 respectively, it is obvious to have

$$d\tau_1 = (1-\frac{2GM}{r_1})^{\frac{1}{2}}dt_1. \tag{14}$$

Here τ_1 is measured by the local clock fixed at the coordinate point p_1, and t_1 is measured by the mathematical clock (background clock). Similarly, we have

$$d\tau_2 = (1-\frac{2GM}{r_2})^{\frac{1}{2}}dt_2. \tag{15}$$

Therefore,

$$\frac{d\tau_1}{d\tau_2} = \frac{(1-\frac{2GM}{r_1})^{\frac{1}{2}}dt_1}{(1-\frac{2GM}{r_2})^{\frac{1}{2}}dt_2}. \tag{16}$$

The frequency measured by the local clock is

$$\frac{\nu_2}{\nu_1} = \frac{d\tau_1}{d\tau_2} = \frac{(1 - \frac{2GM}{r_1})^{\frac{1}{2}} dt_1}{(1 - \frac{2GM}{r_2})^{\frac{1}{2}} dt_2}. \tag{17}$$

We investigate a practical case: p_1 is ar rest at the surface of the sun and p_2 is at rest on the earth. Since above $d\tau_1$ and $d\tau_2$ are both corresponding to one cycle time(or 2π), in consideration of $dt_2 = dt_1$, we also have

$$\frac{\nu_2}{\nu_1} = \frac{d\tau_1}{d\tau_2} = \frac{(1 - \frac{2GM}{r_1})^{\frac{1}{2}}}{(1 - \frac{2GM}{r_2})^{\frac{1}{2}}} < 1. \tag{18}$$

Here the frequency of the light signal ν_2 is measured by the local clock at p_2. Incorporating a fundamental hypothesis that the local frequency of the light signal emitted at the surface of the sun is equal to the frequency of the similar signal emitted on the earth measured by the local clock on the earth, then we can draw a conclusion that the frequency of the light signal emitted from the sun is reduced when it is observed on the earth, comparing with that emitted by the same type of atom on the earth. Ultimately, we demonstrated that the gravitational redshift in the solar system can also be interpreted by the proposed new space-time physical picture.

It can be seen from above discussion, the introduction of a rigid homogeneous coordinate time in mathematical can carry out the comparison of local clocks at different spatial points. More important, the assumption of the equivalence on all free falling clocks has been abandoned in our new physical picture of space-time. On further thought, we may imagine that if all local clocks inside a local system slow down at a same rate, then the dynamical law inside it will still be maintained. So we propose to modify the principle of equivalence that dynamical laws will keep invariant inside any local system in the gravity field, regardless of the state of motion of this local system. While the local clock at this local region will run at a specific rate depending on the intensity of gravitational field. In considering that the proper time interval measured by the local clock is defined by the equation (13), we reach to a corollary that the local space-time at any position in gravity field is of asymptotic Minkowski metric.

Looking back, whether the acceleration and the gravity is completely equivalent or not, are worthy of further investigation. Since the acceleration, according to Newtonian mechanics, is related to all type of forces including the contacting force. The contacting force can change suddenly but the gravity can not achieve this effect because gravity is a long-range universal interaction. Conversely, if the gravity can be completely equivalent to a corresponding acceleration, it is possible to produce a sudden jump on the redshift. It is not natural in physics. Therefore we propose to abandon the assumption that the proper clock in all local inertial reference frames run at the same rate. In fact, the redshift effect caused by the acceleration (or non-gravitational force) can be tested in a ground-based laboratory, and there has been some high energy experiments show that the proper longevity of negative muon is not related to its acceleration[15, 16].

4 NEW COSMOLOGICAL METRIC AND DYNAMICAL EQUATIONS

If the assumption of the equivalence on all free falling clocks is abandon[17], it is necessary to make a corresponding change on the present Friedman-Robertson-Walk cosmological metric so that the gravitational redshift effect can be embodied in the form of the cosmological metric. We know the matter density in the universe changed a lot from the beginning of the unverse, so the strength of gravity also changed greatly. Therefore the gravitational redshift effect is actually worthy to be considered when we establish the cosmological metric.

4.1 the reference frame of the cosmological metric

According to the new physical picture of gravity geometrization, cosmological metric depicts the gravity-induced curve of space-time[5]. The curve must be counted relative to a rigid and homogeneous coordinates system, then the level of the curve reflects the strength of gravity. Therefore, the first step to establish a cosmological metric is to introduce a rigid and homogeneous coordinate system. Before considering of gravity, any an observer with a clock and a ruler always can duplicate his clock and ruler in every space-time point and build up a rigid and homogeneous coordinator system in mathematical. As far as the cosmology is concerned, its observer is implicitly assigned to be the observer at present on the earth. The construction of the coordinates frame must fully incorporate the practical situation of the observer.

In fact, all the analysis and comparison of the observational data about the universe are implemented on the earth. Thus the earth or the comoving galaxy containing the earth is solely qualified to be the origin point of reference frame for the cosmology. Furthermore, the observer on the earth is theoretically able to observe all light signals arrived at the earth whenever they emitted from the universe. But his observation is restricted at the present time and located on the earth. Therefore, the rigid and homogeneous coordinates frame, which is the background for the gravity in the universe to be geometrized, is related with the clock and the ruler of the observer at present on the earth.

4.2 the coordinate frame of the cosmological metric

First, as for spatial coordinates for cosmology, there is a Hubble's principle. So it exists a predominate spatial coordinate system, which can be named as spatial comoving coordinate system. Coordinates of space x^i can be constructed as follows. The center of milk galaxy is set as the reference origin of the spatial coordinate system, the sight line from milk galaxy to some remote typical galaxy are set as the coordinate axis, and the distance is determined by the visibility of the galaxy or other appropriate celestial body[3]. If we adopt the ruler equipped by the earth observer at present as the standard one, then he can duplicate his ruler in every spatial point and build up a rigid and homogeneous spatial coordinator system. We call the ruler of the observer at present on the earth as the cosmological observation ruler. The distance between two comoving coordinate points is evaluated by this cosmological observation ruler. Therefore, the geometry of the curved space reflects the change of the distance between two comoving coordinate points. In the other hand, existing observations support that matter distribution in the universe is isotropic and homogeneous at a large scale. The spatial interval in the comoving coordinate system is given by

$$dl^2 = a^2(t)[\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 sin^2\theta d\phi^2], \tag{19}$$

where k is the curvature of 3-dimension space, dl is the spatial interval for two arbitrary comoving points in the universe.

Second, as for the coordinate time, we also must define it from the viewpoint of observation. We all know that the study of the universe is mainly through the observation of the light signals emitted in the universe. Particularly, the redshift of light signals is one of the most important quantities to investigate the evolution of the universe. The redshift is measured by comparing the light signal with the same type of light signals on the earth at the present time. So the definition of the coordinate time should be related to the clock of present observer on the earth. On the other hand, to geometrize gravity we need a rigid and homogeneous coordinate frame which is also related to the clock of present observer on the earth. We take the rate of the observer's clock as the standard one, duplicate this clock rate in every time-point and build up a rigid and homogeneous coordinate time system. We call this time system as the cosmological observation clock. We use t to denote the reading number of the cosmological observation clock and use coordinate time t in cosmological reference frame.

Now we set up cosmological metric basing on the cosmological principle and the gravity experiments on the solar system. On one hand, the time part of the cosmological metric should be separated from spatial coordinates due to the cosmological principle. On the other hand, there exists gravitational redshift effect observed by gravity experiments on the solar system. We know the matter density in the universe changed a lot from the beginning of the unverse, so the strength of gravity also changed greatly. Therefore the gravitational redshift effect is worthy to be considered when we establish the cosmological metric. Furthermore, the consideration of the gravitational redshift effect is especially necessary in the processing of the cosmic microwave background observational data, when the early universe is a plasma with a relatively high density. Therefore it is reasonable to conjecture that a local clock in the early universe runs in a different rate relative to the rest clock in a null-gravity area. To be distinguished from the cosmological observation clock, the reading number of the local clock in the early universe is denoted by τ. We can describe the time dilation effect of the local clock in the early universe measured by the cosmological observation clock as follows,

$$d\tau = b(t)dt. \tag{20}$$

It must be noticed that here we set $b(t_0) = 1$, which means the coordinate time is equivalently measured by the proper clock of the present observer on the earth. Thus the interval of coordinate time is also a proper time interval but all of them are measured at the present time so that the theoretical determination of the redshift is in accordance with the practical situation of observation.

According to above definition of the time and spatial coordinates, a general cosmological metric can be written as,

$$ds^2 = -b^2(t)dt^2 + a^2(t)[\frac{dr^2}{1-kr^2} + r^2d\theta^2 + r^2sin^2\theta d\phi^2]. \tag{21}$$

In fact, it can be verified that above metric is in a maximum spherical symmetry according to the differential geometry theories of 4 dimensional space-time[3]. Therefore, it is also the most general cosmological metric satisfying the cosmological principle. If the rate of the local clock of the early universe is not subjected to the change of gravity strength, $b(t)$ becomes a constant. Then the cosmological metric (21) can be reduced to,

$$ds^2 = -d\tau^2 + a'^2(\tau)[\frac{dr^2}{1-kr^2} + r^2d\theta^2 + r^2sin^2\theta d\phi^2], \tag{22}$$

which is the Friedman-Robertson-walk (FRW) metric. However, it is well founded that the rate of the comoving clock is subjected to the change of gravity strength, so it is non-trivial to include $b(t)$ in the cosmological metric. The new cosmological metric (21) differs from the equation (22) in only a simple transformation that $d\tau = b(t)dt$ while r, θ, ϕ remains unchanged. But such a coordinate transformation is unsuitable to the fixed observer of the cosmology—the observer at present on the earth. Firstly, if we keep the physical meaning of the coordinate time invariant in the cosmological metric and rescale the coordinate time by absorbing a non-constant factor such as $b(t)$, it would be a nontrivial redefinition of time and bring extra arduous work on the basic measurement. Secondly, if we implement a general relativistic transformation on the cosmological metric (21), the form of the metric (21) may be simplified. However the reference frame and the corresponding observer would be changed at the same time, so does the measure of time. In that case how to unify the theoretical quantities with the practical observation data would be a big trouble. Because we reiterated in this article that conducting cosmic observations is fixed to the observer at present on the earth, instead of any other observers including the local observer in the early unverse.

4.3 the dynamical equation of cosmology

According to the new cosmological metric (21), The non-zero components of Ricci tensor can be easily derived:

$$R_{00} = -3\frac{\ddot{a}}{a} + 3\frac{\dot{a}\dot{b}}{ab} \tag{23}$$

$$R_{ij} = \frac{1}{b^2}(2\frac{\dot{a}^2}{a^2} + \frac{\ddot{a}}{a} - \frac{\dot{a}\dot{b}}{ab})g_{ij} + \frac{2k}{a^2}g_{ij} \tag{24}$$

A consistent energy-momentum tensor may take the following form due to the principle of cosmology[1],

$$T_{\mu\nu} = \rho U_\mu U_\nu + p(\eta_{\mu\nu} + U_\mu U_\nu). \tag{25}$$

As mentioned above, in this article we investigate cosmological dynamics without accepting the full theory of general relativity and all things as it claims. However, we still adopt Einstein field equation as a qualified mathematical form for gravity geometrization which dominates the cosmological dynamics. It has

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi G T_{\mu\nu}. \tag{26}$$

The matter term in above equation can be approximated to be of perfect fluid, which can always be done because the reference point of the cosmological metric is just a comoving point in the universe. Besides, Einstein's equation of gravity is a local field theory which as a dynamical law can always be applied in a local region. Nonetheless, the global kinematics can still be established by means of the cosmological principle after the local kinematics is solved. Therefore, the energy-momentum tensor of the matter in the comoving reference frame has the simple form as

$$T^\mu_\nu = diag(-\rho, p, p, p). \tag{27}$$

Under the cosmological coordinate frame presented in equation (21), the fundamental equations of cosmology is derived:

$$\frac{\dot{a}^2}{a^2b^2} + \frac{k}{a^2} = \frac{8\pi G}{3}\rho \tag{28}$$

$$\frac{1}{b^2}(\frac{\ddot{a}}{a} - \frac{\dot{a}\dot{b}}{ab}) = -\frac{4\pi G}{3}(\rho + 3p). \tag{29}$$

where k is the curvature of space which is not a dynamical variable but a certain value decided by the primary conditions. The cosmic energy density $\rho(t)$ and pressure $p(t)$ can be treated in principle as the functions of two geometrical variables $a(t)$ and $b(t)$. As a complementarity, further research is necessary to put forward a concrete method to solve above system of equations, though in a tentative investigation, we might suppose $b(t) = 1 - \frac{k'}{a(t)}$ in analogous to the counterpart $b(r) = 1 - \frac{2GM}{rc^2}$ in Schwarzschild metric. Here k' is also an undetermined constant.

4.4 physical predicts under the new cosmological metric

At the beginning of this section, we denote λ as the wavelength referring to the present observer on the earth and denote λ'(the primed term) as the wavelength referring to the local observer in the comoving unverse. Without explicitly solving equations (28-29), we are still able to understand the kinematic effects of the expansion (see details in [8]) from the metric (21). Firstly, we assume a light signal is emitted at the moment of t_1 from the comoving coordinate point r_1, and received by a detector localized on the earth r_0 at the moment of t_0. According to the kinematics of light under gravity, the relationship between these two events can be written as,

$$\int_{t_1}^{t_0} \frac{b(t)dt}{a(t)} = \int_{r_1}^{r_0} \frac{dr}{\sqrt{(1-kr^2)}} \equiv f(r_0, r_1). \tag{30}$$

Meantime, the distance between these two comoving coordinate points can be measured by the cosmological observation ruler

$$d_H(t_0) \equiv \int_{r_1}^{r_0} \sqrt{g_{rr}}dr = a(t_0) f(r_0, r_1). \tag{31}$$

We can assume a new wavefront of the light signal is emitted at the moment of $t_1 + \delta t_1$ and received by the detector at the moment of $t_0 + \delta t_0$, then the movement of this new wavefront satisfies the same equation (30). Because the light source and the detector are both fixed on the comoving coordinate points, $f(r_0, r_1)$ is invariant for different wavefronts. Then we have

$$\int_{t_1}^{t_1+\delta t_1} \frac{b(t)dt}{a(t)} = \int_{t_0}^{t_0+\delta t_0} \frac{b(t)dt}{a(t)}. \tag{32}$$

Applying mean value theorem, we obtain

$$\frac{b(t_1)dt_1}{a(t_1)} = \frac{b(t_0)dt_0}{a(t_0)}. \tag{33}$$

Because a light signal propagates along a null geodesic, after further incorporating the cosmological metric the coordinate speed of light can be written as

$$\frac{c(t_0)}{c(t_1)} = \frac{\frac{a(t_0)dr_0}{dt_0}}{\frac{a(t_1)dr_1}{dt_1}} = \frac{b(t_0)}{b(t_1)}. \tag{34}$$

Therefore, if the gravitational redshift effect maintains for the clock localized on the comoving coordinate points, the observer at present on the earth can detect the phenomenon of varying coordinate light speed in the vacuum. Secondly, since Einstein's gravity field equation is locally valid, and its kinematical solution in cosmology is also valid relative to the comoving point inside every local region, so the expansion of the universe moving far away form each other can be equivalent to an expansion of space-time. The wavelength of the light signal propagating between two different comoving points satisfies

$$\frac{\lambda'_0}{\lambda'_1} = \frac{a(t_0)}{a(t_1)}. \tag{35}$$

Recalling the definition of the redshift, we have

$$1 + z' = \frac{\lambda'_0}{\lambda'_1} = \frac{a(t_0)}{a(t_1)}. \tag{36}$$

This is just the same result in the standard cosmology. However, under the new cosmological model, above redshift should be only attributed to the kinematical effect from the expansion, rather than gravitational redshift. An observational redshift should actually further incorporate the gravitational redshift effect by considering it when the light signal being emitted and received. According to the gravitational redshift effect in the solar gravity test, we have

$$\frac{\lambda_1'}{\lambda_1} = \frac{b(t_0)}{b(t_1)}. \tag{37}$$

With previous definition, we always have $\lambda_0' = \lambda_0$. Then we obtain the final value for redshift:

$$1 + z = \frac{\lambda_0}{\lambda_1} = \frac{\lambda_0'}{\lambda_1} = \frac{\lambda_1'}{\lambda_1} \cdot \frac{\lambda_0'}{\lambda_1'} = \frac{b(t_0)}{b(t_1)} \frac{a(t_0)}{a(t_1)}. \tag{38}$$

Since $b(t_0)/b(t_1)$ is greater than 1 and will increase with the decrease of the time t_1 when the universe is expanding, it may diminish the value of apparent acceleration d^2a/dt^2 according to the current observation data.

Furthermore, we should discuss more about the mathematical formula for the acceleration of the universe. As we know, acceleration is not invariant under coordinate transformation, it may change greatly in different reference coordinate systems. When the cosmological metric (21) is adopted, the apparent definition of the acceleration is revised to be $\frac{d^2a}{dt^2}$, instead of $\frac{d^2a}{d\tau^2}$. The relationship between these two definitions of acceleration is given by

$$\frac{d^2a}{d\tau^2} = \frac{1}{b^2(t)} \frac{d^2a(t)}{dt^2} - \frac{1}{b^3(t)} \frac{da(t)}{dt} \frac{db(t)}{dt}. \tag{39}$$

In considering that all comparisons of the redshift of light signals are implemented at the present time, then all the redshift are intrinsically measured by the clock of the present observer on the earth. That is to say, all redshifts are practically evaluated by a coordinate time t which runs at the same rate with the clock of the present observer on the earth. Hence the value of the accelerated expanding speed resulted from current observational data is directly related to $\frac{d^2a}{dt^2}$. We will show that the sign of this expression may be in different with that of $\frac{d^2a}{d\tau^2}$. To illustrate this point, we may investigate the evolution property for $b(t)$ by resorting to the gravitational redshift effect in Schwarzschild metric. There the time dilation factor $1 - \frac{2GM}{rc^2}$ will increase with the distance r, which is equivalent to this factor increase with the decrease of the gravitational strength. Therefore, with the expanding of the universe, the gravitational strength will also decrease, then $b(t)$ will increase with time, $\frac{db(t)}{dt} > 0$ (As a complement, we might suppose in further investigation that $b(t) = 1 - \frac{k'}{a(t)}$ in analogous to $b(r) = 1 - \frac{2GM}{rc^2}$, here k' is a constant). On the other hand, we are easy to see that $\frac{da(t)}{dt} > 0$ for an expanding universe. Now it is possible to have a negative $\frac{d^2a}{d\tau^2} < 0$ according to the equation (39) even $\frac{d^2a}{dt^2} > 0$ is hold. It further means a possibility that $\rho + 3p > 0$ according to the equation (29). Therefore, we must keep in mind two different definitions of the acceleration when we talk about the accelerated expansion of the universe. And what is indicated directly from the practical observation data is $\frac{d^2a}{dt^2}$, rather than $\frac{d^2a}{d\tau^2}$.

5 REMARKS

Firstly, in this article we have presented a feasible and natural approach to achieve the relativity of physical laws among all reference frames. The keypoint is to keep the consistency and symmetry on the relative measurement of the kinematical quantities and the relative counting of the interactional quantities. The first reason for this proposal is that the description of motion for a particle must be relative to a selected reference frame, thus its kinematical quantities should be relative in order to keep the causality consistency. That is possibly the origin of the relativity for dynamical equations. The second reason is that these relative measurement (or counting) must be consistent and symmetric so as to maintain the validity of dynamical equations. On this basis, we propose a novel relativity with the condition of consistency on cause and effect. In the spirit of this approach, the inertial force can be naturally unified into the relative counting of forces and the new principle of relativity is also in accordance with the actual application of Einstein's field equation on the solar gravity. More importantly, theoretically we have found the way in which dynamical equations can be exactly applied in any reference frame. Henceforth the peculiar status for inertial reference frame is canceled. Of course, this modification of Newtonian mechanics can be tested by experiments, but it may need enough high precision. First, whether the counting of the force should be relative is distinguishable in a ground-based laboratory by a mechanical test. Second, we can select an arbitrary "non-inertial" moving object on the surface of the earth as the origin point of a reference frame, then we can check the exactness of dynamical equation

(8). So far, we have at least explained why the frames with the reference origin being fixed at the center of the earth or the center of the sun are both good approximations of so-called inertial reference frames.

According to the principle of invariant light velocity, the exact dynamical equation (3) also needs a relativistic reforming. However, we may directly adopt the form of linear dynamical equation in special relativity. Because the kinematical quantity in the relativistic dynamical equation has been defined in original to be measured relatively, while the relative counting of the force is accompanied by one reference frame introduced in the description initially, instead of re-selecting different reference frames. Since the relative measurement (or counting) with respect to a specific reference frame is the preceding, and the transformation law of these relatively counted quantities between different reference frames is the subsequent, relativistic dynamical equation can be retained form invariant under the principle of causality consistency but the substantial meaning of the force is changed. The total counting of the force should be changed into the relative counting of the force, although the relativistic dynamical equation is Lorentz covariant and the transformation is nonlinear.

secondly, we have proposed a new physical picture of space-time. All reference frames are equivalent on the description of kinematics and their proper clocks run at the same rate. The gravitational time dilation exists in all local clocks in gravity field, regardless of their state of motion. And all the local space-time are of asymptotic Minkowski metric. We find that the new physical picture of gravity geometrization can self-consistently explain the gravitational redshift in the solar system and the assumption of the equivalence on all free falling clocks is not obligatory.

Finally, we introduce a new cosmological metric which is related to the observer at present on the earth. Because the present observer on the earth is the sole qualified reference observer to determine the redshift value of light signals from the early universe. Therefore, compare with FRW metric in the standard cosmology model, we prefer to adopt a rigid and homogeneous coordinate time t which is calibrated by the clock rate at present on the earth. Besides, if the assumption of the equivalence on all free falling clocks is abandon, introducing a mathematical coordinate time is also necessary so that the gravitational redshift effect can be embodied in the cosmological metric. We know the matter density in the universe changed a lot from the beginning of the unverse, so the strength of gravity also changed greatly. Therefore the proper clock at the present time on the earth may not run at the same rate as that in the early universe. Then even the apparent acceleration $d^2a/dt^2 > 0$ is indicated directly from current observational data, it is still possible to have a negative $d^2a/d\tau^2$ according to the gravitational redshift effect. It turns out to be possible to maintain $\rho + 3p > 0$. Following this way, the current cosmological problems is expected to be solved.

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