Relativistic Space-time Based on Absolute Background

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Incorporating the most solid part of the physics in Einstein's theory of relativity, a nontrivial space-time physical picture, which has a slight different from the standard one, is introduced by means of making a further distinction on the space-time background and space-time scales. In this picture, the coordinate scales in gravity geometrized metric is defined by the clock and ruler equipped by the observer. So the coordinate time interval of any two events is measured by mathematical clocks and mathematical rulers, which are duplicated according to the observer's own clock and ruler. In contrast, the proper time interval in gravity geometrized metric is measured by the local proper clock. In principle, the reading number of clocks and rulers are counted by the undergone times of unit proper event intervals. However, the coordinate space-time scale is essentially described by the length of a line segment which is cut from the background of space by the unit proper space-time event intervals. The function of gravity is that the length of the unit proper event intervals is responsible to be changed according to the intensity of gravity. Such a physical picture combines both the intuitive experience and the most solid part of the physics in Einstein's theory of space-time. On this basis, we reformulate a particle dynamical equation which satisfies a more realistic general principle of relativity under the framework of classical mechanics. After that, we discuss the physical picture of the solar gravity being geometrized, and reinterpret the gravitational redshift effect. Finally, we reexamine the form of cosmological space-time metric on which the gravity at the large scale of the universe is geometrized. Since the observer is always related to the unit scales of the coordinates system in the presented space-time physical picture, the current measured cosmic acceleration is substantially a coordinate acceleration, rather than a proper acceleration which is only regarded to be measured by local clocks.
Keywords: Space-time Physical Picture; Absolute Background; Cosmological Metric PACS number(s): 45.20.-d, 45.05.+x

1 INTRODUCTION

As well known to us, the gravitational redshift experiments is one of three traditional verification tests for Einstein's general theory of relativity. The traditional interpretation of the gravitational redshift effect is based on the space-time physical picture given by Einstein's equivalence principle[1, 2]. However, Einstein's equivalence principle is also based on a most weak equivalence principle, namely the equality between the gravitational mass and inertial mass, and further claims that the gravitational force must be equivalent to an inertial force on all their physical effects[3]. Therefore, all free-falling reference frames under gravity are regarded as equivalent local inertial reference frames. The space-time properties in these local inertial reference frames are considered to be exactly the same. The standard interpretation of the gravitational redshift effect from general theory of relativity has been discussed in detail in many textbooks[1–4]. But in the space-time physical picture given by the standard general theory of relativity, space-time can not exist on its own, or can not be isolated from the matter. In other words, a space without any matter can not exist. In contrast, there is a tit-for-tat classical opinion that the space in principle can be isolated from the mass and exist on its own. There is an expression quoted from Einstein to account for the fundamental difference between the classical view of space-time and Einstein's relativistic view of space-time: in the classical view of space-time, the space-time itself, as a stage on which all physical phenomena occur, can still exist even if all the matter disappear from the reality.

Actually, whether the space can exist isolated from matter is a philosophical question. Even by now, all experiments still fail to directly give a definite answer on this issue. Therefore, a new physical picture of space-time to be inconsistent with that of general theory of relativity on this point is not doomed to be hopeless. In fact, in this paper we just want to propose a compromise on this issue. That is to say, the concept of space-time should be further subdivided into two levels. One is the absolute background of space-time, and the another is the space-time scales. The latter can be regarded as a unit line segment which is cut from the absolute space-time background. More specifically, a novel physical picture of space-time with an absolute background which will be examined in this paper is presented as follows.

Firstly, an absolute background of space-time exists in the universe. Here "absolute" means that the background of space always exists homogeneously and infinitely, and the background of time passes homogeneously and immortally. The background of space-time is independent of any matter's motion and distribution in the universe. There is no concept of scales for the background of space-time since the background itself does not contain specific objects. On the contrary, the scales of space-time can only be defined by proper events occurred in real objects. For instance, the background of space-time just like a blank sheet of paper. Originally, there is no coordinates on it. It is nothing but the observation that requires the introduction of coordinate scales. Usually, we define the unit coordinate scales by resorting to the proper events occurred in specific objects, so the coordinate system is established.

Secondly, the time dilation and length contraction effects which are caused by a relative velocity between two reference frames, can be regarded as a kind of observational effect. However, the time dilation and length contraction effects which are caused by gravity, should be understood as a transformation rule of space-time scales. In principle, the space-time intervals of proper events is able to change, but the background of space-time as the basis to reflect this change must be homogeneous forever. As a result, the absolute space-time background implies that the position of any particle in the background of space is objective. In fact, this point is also the foundation of physical logic in Einstein's special theory of relativity. In the derivation of special theory of relativity, it is easy to be found that the position of any physical event is assumed to be objective and irrelevant to the change of reference frames[5], though the coordinates of this position will change with specific observers. Just for this reason, the coordinate transformation rules in special theory of relativity, namely the time dilation and length contraction effect, should not be interpreted as the variation on the background of space-time. Therefore, the existence of an absolute space-time background can be compatible with the special theory of relativity.

Thirdly, the space-time scales are directly defined by unit intervals of proper events occurred in specific objects. In this way, the magnitude of a space-time scale is described by the line segment which is cut from the background of space-time by the two proper events of this unit interval. There are long and short line segments. There are thus large and small space-time scales. In contrast, the reading number of observers' clocks and rulers are substantially determined by the number of times of proper events occurred. Therefore, the reading number of clocks and rulers itself does not directly contain any information of space-time scales. Only under the same length of line segments cut from the background of space-time, the difference of their corresponding space-time scales can be determined by making a comparison of their respective reading number of clocks and rulers.

Finally, in the background of time, the simultaneity always exists in fact according to a basic hypothesis that the background of time passes homogeneously. But an observable simultaneity should be defined manually. For instance, if an observer want to make clear the simultaneity between different space points by means of the observation of physical phenomena, he has to resort to the number of times of proper events occurred on these space points. In other words, the observable simultaneity should be determined by the coordinates of space-time points. Therefore, an observable simultaneity does not always available for us in any cases. But for two events occurred on the same space point, we must be able to distinguish the time order of the occurrence, so we always can retain the concept of simultaneity for the same space point. Specifically speaking, on an accompanying spatial point where the observer stays, the simultaneity can always be defined for all his observed physical phenomena. For instance, in ancient people have no clock, even don't know a method to record the time. But it certainly does not affect the occurrence of many physical events at the same time. Therefore, the simultaneity in the background of time always exist objectively. But the directly observable simultaneity for observers must be defined by resorting to specific physical phenomena.

Based on above physical picture of space-time, this paper aims to reinvestigate main physical proofs which may be closely related to the properties of space-time physics. In Sec.1, an alternative picture of the fundamental physics of space-time is comprehensively expounded as an introduction. In Sec.2, the formulism of particle dynamics under the framework of classical mechanics is investigated. Incorporating the existence of an absolute space-time background, we propose a new dynamical equation according to the causal consistency principle. In Sec.3, we reinterpret the theoretical prediction of gravitational redshift effect by retaining Einstein's gravitational field equation. In Sec.4, we reexamine the formulism of the standard cosmological metric which is the basis in the processing of observational data. In addition, according to above fundamental physical picture of space-time, gravity should be geometrized as follows. Firstly, according to the causal consistency principle, the distribution and motion of matter in Einstein's gravitational field equation should be regarded as a cause, and the geometry of space-time metric can be regarded as the result. Because the energy-momentum tensor is always measured relative to observers, then in theory the space-time metric should also be determined relative to observers. Secondly, a natural approach to determine how the space-time is curved by gravity can be presented. The scales of space-time coordinates is defined according to the clock and ruler equipped by the observer himself. Equivalently, so we can imagine that any space-time intervals are measured by the mathematical clock and mathematical ruler which are duplicated from that equipped by the observer himself. In this way, a rigid and homogeneous space-time coordinates system is established. Therefore, the physical effect of gravity is just reflected by the deviation of real space-time metric from this rigid and homogeneous Minkowski's metric of space-time.

2 GENERALIZATION OF THE RELATIVITY OF PARTICLE DYNAMICS AND EXISTENCE OF AN ABSOLUTE BACKGROUND OF SPACE-TIME

In the framework of Newtonian mechanics, the fundamental dynamics equation is Newton's second law. But as is well known, Newton's second law is only valid in inertial reference frames. Provided that we apply the equation form of Newton's second law in a non-inertial reference frame, we need to introduce a fictitious force—inertial force additionally. The magnitude of the inertial force is usually determined by the relative acceleration between the non-inertial reference frame in question and a certain inertial reference frame[6–12]. Therefore, the Newtonian particle dynamics is totally based on the concept of inertial reference frame. However, as well-known to us, we are never able to find a real inertial reference frame in practice. This situation is surely not satisfactory[4].

In principle, Newton's second law should be a causal law of particle dynamics. Here the forces exerted on the particle under study should be the cause and the resulting acceleration should be the effect. Usually, the traditional theoretical formula of Newton's second law can be given by

$$\mathbf{F}|_p = m_p \mathbf{a}|_{p-O}. \tag{1}$$

In theory, the left hand side of this equation ($\mathbf{F}|_p$) must denote the total force from the whole universe exerted on the particle p. Otherwise, when the equation is applied into concrete cases, we will not be able to make it clear what forces should be included in the count, and what forces should not be counted. The left hand side ($\mathbf{F}|_p$) only depends on p. Yet the right hand side $\mathbf{a}|_{p-O}$ is the acceleration of the particle p with respect to the reference frame O, equivalently measured relative to the reference object of O. Therefore in fact, the effect (namely the result) $\mathbf{a}|_{p-O}$ depends not only on the particle p, but also on the reference object of O which corresponds to the origin point of the reference frame. In this sense, the causality of Newton's second law is not symmetric and consistent in the form. This is the very point to account for why Newton's second law is theoretically valid only in inertial reference frames, but none of them can be found in practice.

Since for Newton's second law, neither the theory nor the causality is satisfactory, we consider whether it is possible to reconstruct the physical logic of particle dynamics. In this process, the only one most fundamental principle which can be resorted to is the causal consistency principle. Then how to solve the problem of causal inconsistency? The key point is how to describe the corresponding effect according to the causal consistency principle, if the total force from the whole universe exerted on the particle is the cause under the consideration. We still suppose that the particle dynamics is certainly to be a theory with causal principle. We regard forces as the cause, and regard accelerations as the effect(result). The total force exerted on a single particle should be objective, namely it will not change with the variation of observers. Therefore, the corresponding effect should also be objective, and not relevant with any reference frame. In this way, a completely objective acceleration can only be expressed as the acceleration with respect to the absolute spatial background of the whole universe,

$$\mathbf{F}|_p = m_p \frac{d^2}{dt^2} \bigodot |_p. \tag{2}$$

Here the objective position of the particle p in the absolute background of space is particularly denoted by $\bigodot |_p$.

The conjecture that an absolute background exists for the space of the universe is mainly originated from our intuitional experiences. Therefore, the absolute background of space (may also be called cosmic spatial background) can be intuitively understood. As the name implies, the spatial background is just what still exists in a space region after all objects inside it were moved away. And the cosmic spatial background is just what still exists in the whole universe after all concrete objects in the universe were moved away. Here "absolute" means that the background of space always exists homogeneously and infinitely, and is independent of the motion and distribution of any matter which exists in the universe. There is no concept of scales for the background of space-time since the background itself does not contain specific objects. On the contrary, only the scales of space-time is defined by proper events occurred in real objects. In principle, the scales of space will change with the spatial intervals of these proper events. For this reason, we must make a physical distinguish between the absolute background and the relative scales of space. For instance, the background of space just like a blank sheet of paper. Originally, there is no coordinates on it. It is the observation that requires the introduction of coordinate scales. Usually, we define the coordinate scales(unit intervals) by resorting to the proper events occurred in specific objects, so the coordinate system is established.

We believe that the motion of all objects in the universe must be performed over this common absolute three-dimensional space background, because only on this basis then the existence of an objective dynamical law is possible. On the other hand, from the logical point of view, we also suppose that every natural principle describing pure relative law must have an absolute basis. There is one point should be emphasized. Here the existence is proposed for absolute background, instead of absolute scales or absolute space-time. Only in this way can the absolute background of space be mostly compatible with the solidest part of modern physics. Newton's absolute view of space-time mainly claims that the measurement of space-time interval is absolute. In contrast, Einstein's special and general theory of relativity can be naturally interpreted as the change rules of space-time scales[1, 5]. All of them are irrelevant to the background of space-time. Moreover, in the logical deduction of Einstein's special theory of relativity, it is easy to see that every event is assumed to have an objective position[5]. In essence, this is the reflection of the existence of absolute background.

Logically, the background should exist for the space of our universe although it is not concrete like general objects. For example, we have known that the dimensions of cosmic spatial background should be of three. But for the absoluteness of cosmic spatial background, strictly speaking, it is an assumption at the level of natural philosophy. Only based on the existence of an absolute background of space, it is possible for us to assume that any particle at any time has its objective position in the universe. We also conjecture that both the number of types of interactions in the universe and their calculation rules are objective. In principle, all kinds of interactions can be recognized and understood by people, and their calculation rules can be ultimately obtained. The reason is that all these interactions must be able to interpret the motions of all objects in the universe, simultaneously and self-consistently.

Above all, to say at least, the existence of the absolute background of space itself is the underlying part of Newton's absolute view of space-time, under the framework of classical mechanics. In this section, we discuss the formulism of particle dynamics just in the framework of classical mechanics. Therefore, it always be rational here for us to reformulate the particle dynamics based on the absolute background of space. Although every particle has its objective position in the absolute background of space, there is still a problem that the objective position in cosmic spatial background can not be directly measured. What we can really measure is the difference between any two objective positions, which substantially constructs a mathematical vector,

$$\mathbf{r}|_{p-O} = \bigodot|_p - \bigodot|_O. \tag{3}$$

After that, we are able to construct a particle dynamical equation which is really available to any observers. In fact, every reference frame must be established on a real reference object. Otherwise, there would be no reference value in measuring any object's motion in the natural world. Therefore, a physical reference frame must be the real reference frame. As for the relationship between the reference object and the reference frame, the reference frame can be naturally established by identifying the reference object as its origin point if we assign a reference object first in practical cases. Otherwise, in principle any real object which is fixed in the reference frame can be identified as its reference object if the reference frame is assigned first. All objects in the universe, including objects under study (p) and reference objects (O), should be of equal status in the most fundamental law of dynamics. For example, the dynamics of any real reference object should also satisfy

$$\mathbf{F}|_O = m_O \frac{d^2}{dt^2} \bigodot|_O. \tag{4}$$

Here the reference object O naturally corresponds to the origin point of a reference frame, so we can establish a reference frame which is irrotational with respect to the absolute background of space. The introduction of reference frames is just to make relative measurements on kinematical quantities. As a causal correspondence, the forces should also be relatively counted in nature.

$$m_O \mathbf{F}|_p - m_p \mathbf{F}|_O = m_p m_O \frac{d^2}{dt^2} (\bigodot|_p - \bigodot|_O) = m_p m_O \frac{d^2 \mathbf{r}|_{p-O}}{dt^2}. \tag{5}$$

Finally, we obtain

$$\frac{\mathbf{F}|_p}{m_p} - \frac{\mathbf{F}|_O}{m_O} = \mathbf{a}|_{p-O}. \tag{6}$$

In this equation, the definition of the force and the acceleration are just the same as that in the traditional theoretical formula of Newton's second law (1). $\mathbf{F}|_p$ and $\mathbf{F}|_O$ are the total forces from the whole universe exerted on the particle p and the reference object O respectively. m_p and m_O denote the mass of the particle p and the reference object O respectively. Since the reference object is definitely fixed in the reference frame, the acceleration ($\mathbf{a}|_{p-O}$) of the particle p is measured relative to the reference object, equivalently with respect to the origin point of the reference frame. Keep in mind, any physical reference frame must be related to a certain real reference object. Therefore, the equation (6) is just the dynamical equation of the particle p with respect to the reference frame O.

In the equation (6), the object under study and the reference object are now placed on an equal status. So the special status for the reference object in the universe is removed. It reflects that all objects in the universe have the equal status in dynamics. That is obvious as well, since what object should be selected as the particle under study, and what particle should be selected as the reference object are essentially assigned by people. In fact, there is no essential division of them. More importantly, the nature of the inertial force is nothing but the real force exerted on the reference object, and which is supposed to appear in the new dynamical equation (6) according to the principle of causal consistency. To demonstrate the difference between the equation (6) and the theoretical formula of Newton's second law (1), we may rewrite (6) to be,

$$\mathbf{F}|_p - \frac{m_p}{m_O}\mathbf{F}|_O = m_p\mathbf{a}|_{p-O}. \tag{7}$$

Here the left hand side of this equation can be called as a relative counting of forces. Obviously, the equation (7) has a net term $(-\frac{m_p}{m_O}\mathbf{F}|_O)$ more than Newton's second law, while the other terms are identical. The equations (6) and (7) are just the new dynamical equation which is proposed to replace the current theoretical formula of Newton's second law under the framework of classical mechanics, since the new dynamical law (6) or (7) presents a more natural and concise physical picture based on reinterpreting all empirical laws from classical mechanics experiments. In the application of (6) or (7), it is easy to find that the inertial reference frame is no longer required and the inertial force is no longer introduced by hand.

Finally, a moderate general principle of relativity is essentially a practical requirement. On one hand, we are never able to know about the actual state of motion of our terrestrial reference frame where our observers exist. On the other hand, we are always able to determine the rotation of any reference frame with respect to cosmic spatial background by resorting to the galaxies far enough away since the cosmic spatial background is objective and motionless. In principle, the exact rotation of any practical reference frame with respect to the absolute background of space can be mathematically solved because the reference frame given in practice must interpret the dynamics for all objects in the universe, simultaneously and self-consistently. Therefore, what the practical observation really requires is that dynamical laws must keep form invariant to all reference frames which are irrotational with respect to the absolute background of space. Furthermore, in particle dynamics, the rotation phenomena can always be attributed to the relative motion between different particles. But for single particle, there is no concept of rotation. In other words, once any reference object is regarded as a particle, no problem of rotation exists for reference particle. Just as the problem of variable mass system under the framework of Newtonian mechanics, the variable mass phenomena should be attributed to the relative motion between different particles in the system of particles, so the fundamental particle dynamical equation is still $\mathbf{F}|_p = m_p\mathbf{a}|_{p-O}$. But for $\mathbf{F}|_p = \frac{d(\mathbf{p}|_{p-O})}{dt}$, it actually can be generalized from the former equation when a system of particles is considered. In this sense, the problem of reference frames' rotation is essentially a mathematical problem. Ultimately, the problem of the rotation of reference frames can be separated from the problem of dynamical relativity.

3 REINTERPRETATION OF GRAVITATIONAL TIME DILATION EFFECT IN SOLAR GRAVITY TEST

According to the principle of causal consistency and the realization of a moderate general principle of relativity on particle dynamics, gravity should be geometrized as follows. Firstly, a reference object and corresponding irrotational reference frame (with respect to the absolute background of space)should be selected so what gravitational forces should be included in the count can be determined. Secondly, the scales of space-time coordinates should be defined according to the clock and ruler equipped by the observer, so a rigid and homogeneous space-time coordinates system is established. Finally, based on this background coordinates system, we determine the curve of space-time by making a comparison between the local proper clock(or ruler) and the mathematical clock(or ruler) duplicated from that of the observer.

Since a quantitative success has been achieved in the solar gravity test by Einstein's gravitational field equation[1, 3], now we reinterpret the gravitational redshift effect[13–15] in the solar system to examine above proposed physical picture of space-time. First of all, all successes in solar gravity test can be attributed to the correctness of Schwarzschild metric. Second, we may retain Einstein's gravitation field equation as a valid formula to describe the geometric theory of gravity, since the concrete process of solving for Schwarzschild metric is not directly related to the specific meaning of the coordinate time t. Third, it must be pointed out that the actual way we derive the Schwarzschild metric by using Einstein's gravitational field equation is in line with the moderate general principle of relativity in Sec.2. More specifically, in the derivation of Schwarzschild metric, the counting of the gravity is restricted to the gravity exerted by objects inside of the solar system. Coincidently, the reference origin is fixed at the center of the solar system.

Therefore, what the solar gravity test has essentially satisfied is the causal consistency principle and the moderate general principle of relativity. Finally, the full expression of Schwarzschild metric is written down,

$$ds^2 = -(1 - \frac{2GM}{r})dt^2 + (1 - \frac{2GM}{r})^{-1}dr^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2. \tag{8}$$

In above equation, unit space-time scales are defined according to the clock and ruler equipped by the observer. In other words, the clock and ruler of the observer are duplicated on the every space-time point in the whole solar system. After that, the time dilation effect is reflected by the difference of the magnitude between the reading number($(1 - \frac{2GM}{r})^{\frac{1}{2}}dt$) of local proper clocks and the reading number(dt) of the mathematical clock and ruler which is duplicated from the observer's clock and ruler, within the same line segment(dt) cut from the background of time. Obviously, at the surface of the sun, we have $(1 - \frac{2GM}{r})^{\frac{1}{2}} < 1$. Therefore, under the condition of same line segment of the background of time (dt), the reading number of the proper clock at the surface of the sun, which is measured by the number of times of local proper events occurred, will be smaller than that of the observer at infinity. In other words, the clock located at the surface of the sun runs slower than that at infinity.

The coordinate time t in the form (8) is actually measured by a mathematical clock initially introduced before the gravity is geometrized. Here the mathematical clock is defined to run at a rigid and homogeneous rate. Therefore, the coordinate time t can be regarded to be equivalently measured by a background clock. For two events occurred on the same spatial coordinate point, their difference on the time intervals measured by the local proper clock and the background clock respectively, embodies the curve of space-time. As for the gravitational redshift effect of light signals from the surface of the sun, strictly speaking, should be calculated by incorporating the specific situation of propagations. Since the gravitational field around the sun is in a vacuum spherical symmetry, the metric of space-time is stationary. In other words, $g_{\mu\nu}$ is irrelevant to the time. Now we assume there are two spatial coordinate points. One is $p_1(\mathbf{r}_1)$. Another is $p_2(\mathbf{r}_2)$. We introduce a light signal that propagates from p_1 to p_2 to investigate the gravitational redshift effect in the solar system. One wavefront is emitted at the moment of coordinate time t_1 and arrives at p_2 at the moment of coordinate time t_2. Thus the time interval measured by the observer's clock (namely the 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 the observer's clock is $\delta t' = t_2' - t_1'$. Considering that the space-time around the sun is stationary, we have

$$\delta t = \delta t', \tag{9}$$

which further indicates

$$dt_2 \equiv t_2' - t_2 = t_1' - t_1 \equiv dt_1. \tag{10}$$

Above equation means that the light signal will keep the cycle time and frequency invariant, which is measured by the observer's clock (background clock) in its propagation to any positions in the gravitational field.

For arbitrary timelike two events: $(t_1, \mathbf{r}_1)$ and $(t_2, \mathbf{r}_2)$, we can define their proper time interval $d\tau$ in analogy to the invariant interval ds in special theory of relativity. So it is given by

$$-d\tau^2 = -(1 - \frac{2GM}{r})dt^2 + (1 - \frac{2GM}{r})^{-1}dr^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2. \tag{11}$$

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

$$d\tau_1 = (1 - \frac{2GM}{r_1})^{\frac{1}{2}}dt_1. \tag{12}$$

Here τ_1 is measured by the local proper clock fixed at the spatial coordinate point p_1, and t_1 is measured by the observer's clock (background clock). Similarly, we have

$$d\tau_2 = (1 - \frac{2GM}{r_2})^{\frac{1}{2}}dt_2. \tag{13}$$

Therefore,

$$\frac{d\tau_1}{d\tau_2} = \frac{(1 - \frac{2GM}{r_1})^{\frac{1}{2}}dt_1}{(1 - \frac{2GM}{r_2})^{\frac{1}{2}}dt_2}. \tag{14}$$

The frequency measured by the local proper clock satisfies

$$\frac{\nu_2}{\nu_1} = \frac{d\tau_1}{d\tau_2} = \frac{(1-\frac{2GM}{r_1})^{\frac{1}{2}}dt_1}{(1-\frac{2GM}{r_2})^{\frac{1}{2}}dt_2}. \tag{15}$$

We investigate a practical case: p_1 is ar rest with respect to 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(namely 2π), in consideration of $dt_2 = dt_1$, we also have

$$\frac{\nu_2}{\nu_1} = \frac{d\tau_1}{d\tau_2} = \frac{(1-\frac{2GM}{r_1})^{\frac{1}{2}}}{(1-\frac{2GM}{r_2})^{\frac{1}{2}}} < 1. \tag{16}$$

Here the frequency of the light signal ν_2 is measured by the local proper clock at p_2. Combining with a fundamental hypothesis that the local frequency of light signal emitted at the surface of the sun is equal to that 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 decreased when it is observed on the earth, compared with the light signal emitted by the same type of atom on the earth. Ultimately, we demonstrate that the gravitational redshift effect in the solar gravity test can also be self-consistently interpreted by the proposed physical picture of space-time.

4 A MORE REALISTIC COSMOLOGICAL METRIC

In principle, any dynamical law should be a causal law. The counting of forces and the measurement of dynamical effects should be in one to one correspondence so that the causal consistency can be guaranteed in dynamical equation[16]. Under the condition that both the counting of forces and the measurement of dynamical effects should be done relatively, every term in dynamical equations must be closely related to the observer, although an arbitrary selection of observers would not affect the validity of the dynamical equations. It has been illustrated by the causal consistency principle in Sec.2 that the dynamical state of the observer is also a key point to correctly apply the dynamical laws. There is one thing should be emphasized that all observations and all determinations of the redshift of light signals from the earlier universe are conducted by the observer at the present time on the earth, rather than an observer comoving with the universe. Specifically speaking, in the determination of the redshift, all observed light signals whether they are emitted one hundred years ago, or one thousand years ago, one million years ago, or one billion years ago, are observed by people on the earth at the present time. That is say that all periods of these signals should be measured by the clock of the observer on the earth at the present time.

Since all large-scale galaxies are in a comoving expanding with the universe, all comoving coordinate points describing these comoving galaxies can be regarded to be in a free falling state. However in traditional theory, the property of the clock in a free falling state is just assumed by Einstein's equivalence principle[1, 2, 19]. Therefore, whether the gravitational force and the inertial force are fully equivalent is worth reexamining. Firstly, it has been demonstrated by an explicit equation (7) that a moderate general principle of relativity can be realized in a very concise picture, which is obviously different with Einstein's view[20]. Moreover, the new dynamical equation (7) also indicates that, the nature of the inertial force is the real force exerted on the reference object. Hence the so-called inertial force can actually be all kinds of interactions such as the gravitational interaction, electromagnetic interaction and so on. But the concept of inertial force still exists in Einstein's special theory of relativity, and even in his general theory of relativity Einstein's equivalence principle still claims that the inertial force is physically equivalent to the gravitational force. More importantly, so far as we know, there is only gravitational force has the time dilation effect. Therefore, Einstein's equivalence principle is neither indispensable nor desirable for the realization of general principle of relativity. Secondly, the clock which is relatively rest in the gravitational field and the clock which is free falling under changing gravity, they differ only in a non-gravitational force and the resulting acceleration. If there is really no gravitational time dilation effect which exists for the free falling clock under changing gravity, it must imply that a non-gravitational force and the resulting acceleration are also able to bring about a time dilation effect for clocks. However, by now there is no such a sign which has been observed and verified in all past experiments. In principle, whether the redshift effect can be aroused by the acceleration 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[21, 22].

For above two reasons, in this paper we only retain the numerical equality between the inertial mass and gravitational mass since it has a solid foundation from experiments. But the assumption that all free falling clocks under gravity run in a uniform rate is given up. We suggest that a local proper clock located in a gravitational field will run at a certain rate which depends on the intensity of gravitational field, even for the local proper clock in a locally free falling state. That will not be in conflict with our experience. Because we may imagine that if the running rates of all clocks inside a local region slow down at a same rate, the dynamical law inside of this region will still be maintained. Therefore, the candidate for the standard clock which is used to compare the rates of clocks must be changed. According to the gravitational time dilation effect and the causal consistency principle, the running rate for the clock equipped by the observer himself is most naturally to be set as the reference scale in cosmological metric. In mathematics, the clock equipped by the observer himself can be duplicated by imagination on to all space-time points. In theory, the geometrical effect resulted by the gravitational field is described by the difference between above observer-based standard clock and the local clocks.

According to above discussion, there are two points of physical considerations should be fully incorporated in the construction of cosmological metric. Firstly, gravity should be geometrized on the basis of a rigid and homogeneous coordinate system of the observer. Most naturally, the clock and ruler of the observer should be duplicated on all the space-time points, so the geometric effect of the gravity can be quantitatively described by making a comparison between the local proper clock (or ruler) and the observer's clock (or ruler). Secondly, we know the matter density in the universe has changed a lot from the beginning of the unverse, so the intensity of gravitational field has also changed appreciably. There is an evolution of the running rate exists for every local clock fixed on the comoving galaxies of the universe. Therefore, incorporating the long evolution history of the universe which the cosmology should study, the construction of cosmological metric must exactly distinguish the present observer's clock on the earth from the local clock on the comoving galaxies.

As for spatial coordinates of cosmological metric, there is a Hubble's principle which predicts a predominate spatial coordinate system named as spatial comoving coordinate system[17, 18]. In principle the observer can duplicate his ruler to every spatial point and build up a rigid and homogeneous spatial coordinator system. We give the ruler of the observer at the present time on the earth the name of "the cosmological observation ruler". The spatial interval of comoving coordinate points is just measured by this cosmological observation ruler,

$$dl^2 = a^2(t)[\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 sin^2\theta d\phi^2]. \tag{17}$$

Although the comoving galaxies are selected as the spatial coordinate points in cosmological metric, but the cosmological observer is still fixed to be the observer at the present time on the earth. Therefore, the distance between cosmological comoving coordinate points should be measured by the present observer's ruler on the earth. In principle we can only study the local space-time property by solving cosmological dynamics equations around the comoving point where the earth located. But by resorting to the cosmological principle, the solved local space-time property can be easily extended into the global space-time property for the whole universe.

As for the coordinate time, we must also define it from the observer point of view. We all know that the study of the universe is mainly based on the observation of light signals emitted from the earlier universe. The redshift of light signals is a particularly important quantity to study the evolution of the universe. The redshift is determined by comparing a received light signal with the same type of light signals on the earth at the present time. Therefore, the coordinate time should be defined resorting to the clock of the observer at the present time on the earth. We take the present observer's clock rate as the standard scale, duplicate this clock rate on every time-point and build up a rigid and homogeneous coordinate time system. We give this time system the name of "the cosmological observation clock". We use t to denote the reading number of the cosmological observation clock. On the other hand, we know the matter density in the universe has changed a lot from the beginning of the unverse, so the intensity of gravitational field has also changed appreciably. On the other hand, based on above discussion, a local proper clock in the earlier universe, regardless of its state whether it is free falling or not, is supposed to run in a different rate with respect to the clock under null gravity. To be distinguished from the cosmological observation clock, the reading number of the local proper clock which is fixed on the comoving galaxy in the earlier universe is denoted by τ. The time dilation effect is expressed by

$$d\tau = b(t)dt. \tag{18}$$

It must be noticed that if we set $b(t_0) = 1$, which also means that the coordinate time t is equivalently measured by the proper clock of the present observer on the earth. In other words, the interval of coordinate time is actually a kind of proper time intervals but all of them are measured by the clock of the observer at the present time. More specifically, for the observer at the present time, any dt of any events can be regarded as his proper time interval.

According to above definition of the time and spatial coordinates, a general cosmological metric can be written as[23],

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

In fact, above form is also the most general form for cosmological metric under the condition of the cosmological principle. We propose the metric (19) to replace the well known Friedman-Robertson-Walker (FRW) metric [1, 17, 18] in processing observation data. The reason is what we reiterated in this paper that cosmological observations are always made by the observer at the present time on the earth, instead of any other observers including the comoving observer in the earlier unverse.

Furthermore, we discuss the mathematical expression for the acceleration of the universe. As we know, acceleration is not invariant under coordinate transformation, namely it will change explicitly in different coordinate reference frames. Once the cosmological metric (19) is adopted, the definition of the phenomenological acceleration should be revised to be $\frac{d^2a}{dt^2}$, instead of $\frac{d^2a}{d\tau^2}$, since t is the only proper time coordinate for cosmological observers—the observer at the present time on the earth. $\frac{d^2a}{dt^2}$ may be called as the coordinate acceleration and $\frac{d^2a}{d\tau^2}$ may be called as the proper acceleration. The relationship between these two definitions of acceleration is given by[23]

$$\frac{d^2a}{d\tau^2} = \frac{1}{b^2(t)}\frac{d^2a(t)}{dt^2} - \frac{1}{b^3(t)}\frac{da(t)}{dt}\frac{db(t)}{dt}. \tag{20}$$

In considering that all comparisons of the frequency of light signals are implemented at the present time, all redshifts are intrinsically measured by the clock of the present observer on the earth. That is to say, all redshifts are essentially evaluated by the coordinate time t, which has been defined to run at the same rate with the clock of the present observer on the earth. Hence the value of the phenomenological acceleration of expanding, which can be resulted from current observational data, is directly related to $\frac{d^2a}{dt^2}$. It has been shown by the equation (20) that the sign of this term may be in different with that of $\frac{d^2a}{d\tau^2}$. To illustrate this point, we may investigate the evolution property of $b(t)$ in analogy to the gravitational time dilation effect in Schwarzschild metric. In that case the time dilation factor $\sqrt{1-\frac{2GM}{rc^2}}$ increase with the distance r. So we expect that the factor $b(t)$ may increase with the decrease of the gravitational field intensity. With the expanding of the universe, the gravitational field intensity decreases, then $b(t)$ will increase with time. It indicates $\frac{db(t)}{dt} > 0$. On the other hand, we have $\frac{da(t)}{dt} > 0$ for an expanding universe. Hence it is possible to have a negative $\frac{d^2a}{d\tau^2}$ according to the equation (20) even $\frac{d^2a}{dt^2} > 0$ holds. Therefore, in order to make a correct judgement on the physical nature of the acceleration of our universe[24, 25], it is meaningful to introduce a cosmological observation metric according to the observer at the present time on the earth. We must keep in mind that there are two different concepts of the acceleration when we talk about the accelerated expansion of the universe. The acceleration indicated directly from the practical observation data is $\frac{d^2a}{dt^2}$, rather than $\frac{d^2a}{d\tau^2}$.

5 CONCLUSION

In this paper we have investigated a series of physical proofs which may be related to the physical picture of space-time, including the formulism of particle dynamics under the framework of classical mechanics, the gravitational time dilation effect of solar gravity test and cosmological observation space-time metric. All these fundamental physics are proved to be compatible with our new proposed space-time physical picture with an absolute background. In this way, a novel space-time physical picture based on the absolute background is systematically presented in this paper. Here the key point is that in concept we should further distinguish the background of space-time from the scales of space-time. The background of space-time is absolute, and the scales of space-time is relative. It is just the scales of space-time satisfy the theories of relativity.

Acknowledgments: The author would like to thank all his friends who have provided their constructive criticisms and comments. This work has been supported from the Nature Science Foundation of Zhejiang Province under the grant number Y6110778. This research was supported in part by the Project of Knowledge Innovation Program (PKIP) of Chinese Academy of Sciences, Grant No. KJCX2.YW.W10. This report is dedicated to my grandfather Mr.Chen ChengDong.

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[1] Steven. Weinberg, Gravitational and Cosmology: Principles and Applications of the General Theory of Relativity (John Wiley & Sons, Inc, New York, 1972), Part 3.
[2] John M. Stewart, Advanced General Relativity, Cambridge University Press, 2003.
[3] Ohanian, Hans C; Ruffini, Remo. Gravitation and space-time, Publisher: W. W. Norton Company; Second Edition.
[4] Liu Liao, General Relativity (High Education Press, Shanghai, China, 1987), pp 26-30; 188-190.
[5] Zhang SanhuiUniversity Fundamental Physics Tsinghua University Publishing House, 2009.
[6] Chen, S.Z., General Physics (Higher Education Press, Sixth Edition, 2006). ISBN 9787040200591.
[7] Jesseph, D.M., Leibniz, on the Foundations of the Calculus: The Question of the Reality of Infinitesimal Magnitudes. Perspectives on Science **6**, 6-40(1998).
[8] Landau, L.D., Lifshitz, E.M, Mechanics Course of Theoretical Physics, [Volume 1](Franklin Book Company, 1972). ISBN 0-08-016739-X.
[9] Feynman, R., Lectures on Physics,(Perseus Publishing, 1999). ISBN 0-7382-0092-1.
[10] Daniel, K., Robert J. K., An Introduction to Mechanics, (McGraw-Hill, 1973). ISBN 0-07-035048-5.
[11] Herbert, G., Charles, P.P., Stewart, J.L., Classical Mechanics, (Addison Wesley, 3rd ed, 2002). ISBN 0-201-65702-3.
[12] Alexander, L F., John D W., Theoretical Mechanics of Particles and Continua, [33C39] (Courier Dover Publications, 2003). ISBN 0-486-43261-0.
[13] Pound, R. V. Snider, J. L. Effect of gravity on gamma radiation. Phys. Rev. 140, B788CB803 (1965).
[14] Hafele, J. C. Keating, R. E. Around-the-world atomic clocks: observed relativistic time gains. Science 177, 168C170 (1972).
[15] R. F. C. Vessot, et al. Test of relativistic gravitation with a space-borne hydrogen maser. Phys. Rev. Lett. 45, 2081C2084 (1980).
[16] ChiYi Chen, The Realization of General Principle of Relativity in Particle Dynamics, hep-th/0312225V9. http://www.paper.edu.cn/download/downPaper/201305-209/1.
[17] H. Bondi, M.A. and F.R.S., COSMOLOGY, The Cambridge University Press, 1960.
[18] Edward W.Kolb and Michael S.Turner, The Early Universe , Addison-Wesley Publishing Company.
[19] Haugen, Mark P.; C. Lmmerzahl (2001). Principles of Equivalence: Their Role in Gravitation Physics and Experiments that Test Them. Springer. arXiv:gr-qc/0103067. ISBN 978-3-540-41236-6.
[20] Bernard F. Schutz, A first course in general relativity, Cambridge Univers press,1985.
[21] Farley F J M, et al. The anomolous magnetic moment of the negative muon. Nuovo Cimento A, 1966, 45, 281.
[22] J.Bailey, et al. Measurements of relativistic time dilation for positive and negative muons in a circular orbit, Nature, 288, p301, (1977).
[23] ChiYi Chen, On the Dynamical Relativity Principle and Cosmological MetricarXiv:hep-th/0411047v9. http://www.paper.edu.cn/download/downPaper/201206-337/3.
[24] Perlmutter, S., Aldering, G., Dellva Aalle, M., et al. (1998). Nature 391, 51-54, astro-ph/9712212.
[25] Bennett, C. L., Halpern, M., Hinshaw, G., et al. (2003). Astrophys.J.Suppl. 148, 1, astro-ph/0302207.