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The Coupling between Cosmic Expansion and Gravity Causes the Accelerated Expansion

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Abstract There exists a new coupling effect between cosmic expansion and gravity. With this new gravitational coupling, we can simply explain the phenomenon of accelerated expansion of the universe. The calculation results are in full agreement with the cosmological measurements. This proves that the new gravitational coupling is the dark energy. Dark energy does not exist. This theoretical model brings about a new coupling constant for the coupling effect. The value of this coupling constant can be measured by measuring the cosmic redshift at the inflection point of the expansion speed of the universe.

Keywords: *cosmology, Planck Gravity Theory, Friedmann equation, cosmic expansion, accelerated expansion, dark energy, gravity coupling, coupling constant, Hubble constant, cosmic redshift, inflection point, inflection radius, cosmic mass, gravitational acceleration*

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1. Introduction

Since the discovery of the accelerated expansion of the universe [1,2], how to explain this phenomenon in theory has become a big problem in physics and cosmology. Humans have come up with various theories to explain this phenomenon. The dark energy was also proposed [3]. The researchers propose that the force that causes the universe to accelerate its expansion comes from a mysterious energy unknown to human beings, which is called dark energy. Dark energy, in contrast to conventional matter, does not produce gravitational pull, but repulsive force, so it causes the universe to expand at an accelerated rate. The researchers hypothesized an energy unknown to humans and mysterious. It is this energy that causes the universe to expand at an accelerated rate. This energy is called dark energy. Dark energy is the opposite of conventional matter. Dark energy does not produce gravitational pull, but repulsion, so it causes the universe to expand at an accelerated rate. However, humans have not been able to detect dark energy in experiments. Humans have been unable to confirm the existence of dark energy. Whether dark energy really exists, and what kind of properties dark energy has. This becomes a big problem in physics and cosmology. If the cause of the accelerated expansion of the universe is not dark energy, then what will be the reason? Is it possible for humanity to find the cause of the accelerated expansion of the universe within the scope of known physical theories? On the issue of the accelerated expansion of the universe and dark energy, humanity seems to have reached a dead end and cannot find a way out. Humanity desperately needs new ideas to solve this big problem.

The authors propose a new Planck Gravity Theory [4,5]. The theory has a lot of new ideas and reveals a lot of new gravitational properties. In Planck Gravity Theory, the author found a new coupling effect between cosmic expansion and gravity. With this new gravitational coupling effect, we can simply explain the phenomenon of accelerated expansion of the universe. So we can solve the problem of dark energy. This paper is an introduction to this theoretical model.

2. Cosmology Equation in Planck Gravity Theory

In Planck gravity theory [4,5], an object moves in the gravitational field of mass M. The gravitational potential energy of the object is formula (1.1).

$$U = \frac{GMm}{r} = \frac{r_0}{r} mC^2 \tag{1.1}$$

The r_0 is scale constant of the gravitational field. It identifies the strength of the gravitational field. If the mass of the gravitational source is M, the scale constant is formula (1.2).

$$r_0 = \frac{GM}{C^2} \tag{1.2}$$

In formula (1.1), the mass m satisfies formula $C^2 = \sqrt{P^2C^2 + m_0^2C^4}$, which is the mass-energy equation.

The gravitational potential energy is negative. So the total energy of object moving in the gravitational field is formula (1.3).

$$E=\left(1-\frac{r_0}{r}\right)mC^2 \tag{1.3}$$

For an object moving in a gravitational field, its total energy E is conserved, so it is a constant. We use E_0 to identify the total energy. From (1.3), we can get.

$$m=\frac{E_0}{C^2\left(1-r_0/r\right)}$$

So we get.

$$\ln m=\ln\left(\frac{E_0}{C^2}\right)-\ln\left(1-\frac{r_0}{r}\right)$$

$$\frac{d\left(\ln m\right)}{dr}=-\frac{d\left(\ln\left(1-\frac{r_0}{r}\right)\right)}{dr}=-\frac{r_0}{\left(r-r_0\right)r}$$

In the case of a weak gravitational field approximation, r_0 is a small item, r is a larger item, so we can get.

$$\frac{d\left(\ln m\right)}{dr}=-\frac{r_0}{r^2} \tag{1.4}$$

Referring to the theoretical derivation method of literature [5,6], we can also derive the cosmology equations in Planck gravity theory. According to the cosmological principles and the law of gravity, The gravitational attraction on an object is the gravitational attraction generated by the matter inside the sphere. The gravitational attraction of objects at the edge of the universe is the gravitational attraction generated by the total cosmic matter.

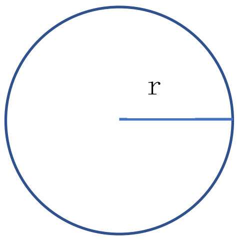

Figure 1.

The gravitational attraction of object at the edge of the universe is formula (1.5).

$$F=\frac{dP}{dt}=\frac{d\left(mV\right)}{dt}=\frac{dU}{dr} \tag{1.5}$$

$$\frac{d\left(mV\right)}{dt}=m\frac{dV}{dt}+V\frac{dm}{dt} \tag{1.6}$$

$$V\frac{dm}{dt}=V\frac{dm}{dr}\frac{dr}{dt}$$

So we get the formula below.

$$m\frac{dV}{dt}+V\frac{dm}{dr}\frac{dr}{dt}=-\frac{r_0mC^2}{r^2}+\frac{r_0C^2}{r}\frac{dm}{dr}$$

Both sides are divided by m, so get.

$$\frac{dV}{dt}+V\frac{dm}{mdr}\frac{dr}{dt}=-\frac{r_0C^2}{r^2}+\frac{r_0C^2}{r}\frac{dm}{mdr}$$

$$\frac{dV}{dt}+V\frac{d\left(\ln m\right)}{dr}\frac{dr}{dt}=-\frac{r_0C^2}{r^2}+\frac{r_0C^2}{r}\frac{d\left(\ln m\right)}{dr}$$

Take formula (1.4) into above, so get.

$$\frac{dV}{dt}-V\frac{r_0}{r^2}\frac{dr}{dt}=-\frac{r_0C^2}{r^2}\left(1+\frac{r_0}{r}\right)$$

$$\frac{dV}{dt}=-\frac{r_0C^2}{r^2}\left(1+\frac{r_0}{r}\right)+V\frac{r_0}{r^2}\frac{dr}{dt}$$

In the case of a weak gravitational field approximation, $\frac{r_0C^2}{r^2}\frac{r_0}{r}$ is a small item, so we can omit it, so we get.

$$\frac{dV}{dt}=-\frac{r_0C^2}{r^2}+V\frac{r_0}{r^2}\frac{dr}{dt} \tag{1.7}$$

The equation (1.7) is the gravitational acceleration equation in Planck gravity theory, which adds a new item to Newton's gravitational acceleration equation. The new item is $V\frac{r_0}{r^2}\frac{dr}{dt}$.

In the derivation of the above formula, only the radial motion of objects is actually considered for the contraction and expansion of the universe. Therefore, the r in the above formula is the radial radius of the universe, and the speed of the object is the radial velocity. In formula (1.7), $V=\frac{dr}{dt}$, so can get (1.8).

$$\frac{dV}{dt}=-\frac{r_0C^2}{r^2}+\frac{r_0}{r^2}\left(\frac{\mathrm{dr}}{\mathrm{dt}}\right)^2 \tag{1.8}$$

Formula (1.8) is actually (1.9).

$$\frac{dV}{dt}=-\frac{r_0C^2}{r^2}+\frac{r_0V^2}{r^2} \tag{1.9}$$

In regular gravitational situation, the universe does not expand, $\frac{r_0V^2}{r^2}$ is small item obviously, so we can omit it. But let's analyze $\frac{r_0V^2}{r^2}$ carefully. This item contains item of radial velocity. Because the universe is expanding, the radial distance is increasing. $V=\frac{dr}{dt}$ is actually the rate at which the universe is expanding. According to Hubble's law, the rate of expansion increases with distance. When the distance is large, the expansion rate will become very large. $\frac{r_0V^2}{r^2}$ will be a large item, and it will not be able to be omitted. This is a special effect of the expansion of the universe. This effect can be seen as a coupling between cosmic expansion and gravity. This coupling effect only occurs in exceptional cases of the expansion of the universe. This coupling effect does not occur in other conventional gravitational cases. Therefore, in the special case of the expansion of the universe, the acceleration of Planck gravity has a special gravitational coupling effect than the acceleration of Newton gravity. This is a peculiar result of Planck gravity.

Borrowing ideas from Hubble's law, but obviously, here V cannot be equal to Hr, H is the Hubble constant. Therefore, we need to introduce a new constant to represent this gravitational coupling effect, so we introduce the following formula.

$$V = \frac{dr}{dt} = Ar \tag{1.10}$$

Here A is a constant that identifies the coupling properties between the expansion of the universe and gravity. A is the coupling constant. It is a new constant. The value of A is waiting to be determined.

Please pay attention. The formula (1.10) is valid only for the second term of formula (1.9), which is used to represent this coupling effect. The coupling constant A only be used to identify the coupling properties in $\frac{r_0 V^2}{r^2}$. It cannot be used in other cases. Please readers distinguish this carefully to avoid conceptual confusion.

$$\frac{r_0 V^2}{r^2} = \frac{r_0}{r^2}(Ar)^2 = A^2 r_0 \tag{1.11}$$

Formula (1.11) represents the coupling effect between the expansion of the universe and gravity.

Take (1.11) into (1.9), so get formula (1.12).

$$\frac{dV}{dt} = -\frac{r_0 C^2}{r^2} + A^2 r_0 \tag{1.12}$$

Because $r_0 = \frac{GM}{C^2}$, $V = \frac{dr}{dt}$, so (1.12) is (1.13) actually.

$$\frac{d^2 r}{dt^2} = -\frac{GM}{r^2} + \frac{A^2 GM}{C^2} = \frac{GM}{r^2}\left(\frac{A^2 r^2}{C^2} - 1\right) \tag{1.13}$$

Obviously, as the universe expands and r gets bigger, gravitational acceleration will change from negative to positive. Gravitational acceleration has an evolutionary process of first decelerating and then accelerating. There is an inflection point in the middle that slows down to acceleration. This is exactly how the expansion of the universe evolved. So, we see, this equation can explain the evolution of the expansion of the universe.

According to cosmological principles and the expression of the expansion of the universe, we define a comoving coordinate system.

$$r = a(t)x \tag{1.14}$$

Let's define the density of matter in the universe.

$$M = \frac{4\pi\rho r^3}{3}$$

From formula (1.13), we can get formula (1.15).

$$\begin{aligned} \frac{\ddot{a}}{a} &= \frac{4\pi G\rho}{3}\left(\frac{A^2 a^2 x^2}{C^2} - 1\right) \\ &= \frac{4\pi G\rho}{3}\left(\frac{A^2 a^2 x^2}{C^2} - 1\right) = \frac{4\pi G\rho}{3}\left(\frac{A^2 r^2}{C^2} - 1\right) \end{aligned} \tag{1.15}$$

In the Planck gravity theory, (1.15) is the Friedmann acceleration equation obtained in the case of a weak gravitational field approximation, and ignoring the radiation state at the beginning of the universe. There is a correlation between the acceleration of the expansion of the universe and the radius of the universe.

In the same way, in the case of a weak gravitational field approximation, and ignoring the radiation state at the beginning of the universe, we can derive the Friedmann velocity equation in the Planck gravity theory.

$$\left(\frac{dr}{dt}\right)^2 = \frac{2GM}{r} + 2A^2 r_0 r + k = \frac{2GM}{r}\left(\frac{A^2 r^2}{C^2} + 1\right) + k$$

The Planck gravity theory is a flat geometry theory with zero curvature of space-time. The actual measured curvature of the universe is zero also. So k=0, so get formula below.

$$\left(\frac{dr}{dt}\right)^2 = \frac{2GM}{r} + 2A^2 r_0 r = \frac{2GM}{r}\left(\frac{A^2 r^2}{C^2} + 1\right) \tag{1.16}$$

$$\begin{aligned} \left(\frac{\dot{a}}{a}\right)^2 &= \frac{8\pi G\rho}{3}\left(\frac{A^2 a^2 x^2}{C^2} + 1\right) \\ &= \frac{8\pi G\rho}{3}\left(\frac{A^2 r^2}{C^2} + 1\right) = \frac{2GM}{r^3} + \frac{2A^2 r_0}{r} \end{aligned} \tag{1.17}$$

From the above derivation, we can see. In Planck gravity theory, in the case of a weak gravitational field approximation, without taking into account the radiation state of the early universe, because there is a new coupling effect between cosmic expansion and gravity, so we can simply express the evolution of the expansion rate of the universe, and we can simply explain why there is a transition process from deceleration expansion to accelerated expansion of the universe.

We can see a result from the formula (1.13). As long as the coupling constant A is small enough, when the cosmic radius r is small, the coupling effect of Ar is a small item, and the coupling effect is not obvious enough. At this stage, the gravitational attraction dominates, and the total gravitational acceleration is negative. So the universe slows down the expanding.

When the universe expands to a stage, the cosmic radius r becomes large enough that the coupling effect is significant enough. At this stage, the coupling effect exceeds the gravitational attraction, the coupling effect dominates, and the total gravitational acceleration shifts to a positive value. So the expansion of the universe accelerated.

This is a very unexpected result. Gravity does not always have an attraction effect. Under special conditions, gravity can also have a repulsive effect. Humans need a new understanding to gravity.

3. Coupling Constant

Using the formula (1.13), we can measure and calculate the coupling constant A. When the acceleration of the expansion of the universe becomes zero, it is the inflection point of the expansion rate of the universe. We use r_i to identify the radius of the universe at this time, which is the inflection point radius of the expansion rate of the universe. From formula (1.15), at the inflection point, we can get formula (2.1).

$$Ar_i = C \tag{2.1}$$

At the inflection point of the expansion of the universe, the product of the coupling constant and the radius of the universe is exactly the speed of light C. For actual cosmological measurements, the cosmological redshift at the inflection point stage is about 0.5 [3].

There is the following formula between cosmic redshift and cosmic radius.

$$r = \frac{R}{1+Z} \tag{2.2}$$

Where R is the current cosmic radius. We take (2.2) into (2.1), so can get the formula for the coupling constant A.

$$A = \frac{C\left(1+Z_i\right)}{R} \tag{2.3}$$

The current cosmic radius R is about 4.3×10^{26}m, and the cosmological redshift at the inflection point stage is about 0.5, so we can calculate that the value of A is about 1.04×10^{-18}/s.

After calculating the coupling constant, according to the formula (1.12), we can calculate the equivalent mass density of coupling effect, where ρ is the density of matter in the universe when the radius of the universe is r.

$$\rho_A = \frac{A^2 r^2}{C^2}\rho \tag{2.4}$$

We can see that the equivalent mass density is not a constant. It changes with the radius of the universe.

From formula (1.13), we can get the equivalent mass of coupling effect. The M is the total mass of matter in the universe. The M is a constant.

$$M_A = \frac{MA^2 r^2}{C^2} = \frac{4\pi r^3 \rho_A}{3}$$

So we can get another formula (2.5) about the equivalent mass density of coupling effect.

$$\rho_A = \frac{3A^2 M}{4\pi C^2 r} \tag{2.5}$$

The equivalent mass density decreases as the radius of the universe increases. But the density of matter of the universe satisfies $\rho = \frac{3M}{4\pi r^3}$. Obviously, as the radius of the universe increases, the equivalent mass density decreases at a rate of one square, while the matter density decreases to a cubic rate. The latter decreases much faster. So as the universe expands, the equivalent mass density of coupling effect will eventually be greater than the matter density of universe.

We take (2.3) into (2.4), so can get a result. The equivalent mass density of coupling effect is formula (2.6).

$$\rho_A = \frac{A^2 R^2}{C^2}\rho = \left(\frac{C\left(1+Z_i\right)}{R}\right)^2 \frac{R^2}{C^2} = \left(1+Z_i\right)^2 \rho \tag{2.6}$$

This result is extremely simple, but very surprising. The exact equivalent mass density depends on precise measurements of cosmic redshift at the inflection point stage of the expansion rate of the universe. For actual cosmological measurements, the cosmological redshift at the inflection point stage is about 0.5. So we can get $\rho_A \approx 2.25\rho$. Actual cosmological measurements show that dark energy accounts for about 70% and matter for about 30% in the current universe. The equivalent mass density of coupling effect is very close to the measured dark energy density of the current universe.

From formula (1.13), we can see that. The magnitude of the coupling effect depends on the size of the cosmic radius. The value of the coupling constant is very small. The value of the coupling constant is very small. Therefore, in the space of the universe at a small distance, the coupling effect will not manifest itself obviously. This coupling effect can only manifest itself significantly over a wide range of space.

This new coupling effect between the expansion of the universe and gravity works similarly to hypothesized dark energy, with similar densities of equivalent matter. Therefore, it can be considered that this gravitational coupling effect is hypothetical dark energy. So, dark energy doesn't actually exist.

It can be seen that this theoretical model is consistent with cosmological experimental measurements. So we prove that this coupling model is a theoretical model in line with reality.

Acceleration is related to the strength of the force. From formula (1.13), the coupling effect is equivalent to a cosmic background force. The strength of this force remains constant at any time and in any place in the universe. This is very similar to hypothetical dark energy. But instead of the density remaining constant, the strength of the force remains constant.

In physics, how should we understand this new coupling effect? Let's look at the physical origin of this gravitational coupling effect further. It is derived from the second term in the formula (1.6). Compared with Newton gravity, there is one more item $V\frac{dm}{dt}$ in the formula (1.6). The first item is Newton gravitational acceleration. The second item is a correction for the Newton gravitational acceleration actually. In Planck Gravity Theory, the momentum of the object P=mV. Both m and V are variations. So the gravitational acceleration has one more correction. This correction of gravitational acceleration is related to the velocity of the object. And because of the expansion of the universe, the speed of the object is related to the expansion of the universe. As a result, a coupling between the expansion of the universe and gravity is created, resulting in a coupling effect. It is this extra acceleration correction that brings about the coupling between cosmic expansion and gravity, which brings about the effect of accelerating cosmic expansion.

Formula (1.10) introduces a coupling constant. This formula is very similar to Hubble's law. Hubble's law indicates that the universe is expanding. So we can assume that this coupling constant also represents another new expansion effect. We can think of this coupling effect as an independent expansion effect. If gravity does not exist in the universe, then the universe is expanding at the rate indicated by the formula (1.10). The coupling constant A remains constant, that is, the expansion coefficient remains constant. This expansion of the universe without gravity can be seen as a background expansion of the universe. The coupling constant is the expansion coefficient of the background expansion. Now let's add gravity to this background expansion. So background expansion and gravity create a coupling, and formula (1.11) represents this coupling effect. Because gravity is attraction, it should slow down the rate of background expansion. Gravity and background expansion are superimposed, resulting in the expansion of the real universe observed by humans. The result of the combined action of background expansion, gravity, and coupling is the expansion of the real universe observed by humans. The coupling constant represents the property of background inflation. The Hubble constant represents the properties of the expansion of the real universe.

Of course, this is only a perspective conducive to understanding the concept, and may not be true. Or rather, it's just an assumption. However, we can use such a perspective to deepen our understanding of the concept. Whether there is a background expansion independent of gravity in the real universe is still unknown. However, this question is well worth further study. Gravity itself is attraction, and the measured curvature of the real universe space-time is also zero, how can the expansion of the universe be observed? The authors speculate that the real reason for the expansion of the universe does not originate from gravity. Gravity simply affects the expansion of the universe. The real reason for the expansion of the universe is not yet known to humans.

From the formula (1.13), it can be seen that as the radius of the universe increases, the acceleration of objects at the edge of the universe will become more and more towards a constant value.

From the formula (1.16), it can be seen that as the radius of the universe increases, the speed at which objects at the edge of the universe move away will increase, eventually tending to the linear proportion of the radius of the universe. The greater the radius of the universe, the greater the speed away from it.

From the formula (1.17), it can be seen that as the radius of the universe increases, the expansion coefficient of the universe will become smaller and smaller, and will eventually become zero.

Please pay attention. The entire description of this paper has a precondition, that is weak gravitational approximation, and also ignores the radiation pressure at the beginning of the universe. Therefore, the description process of the entire paper is not valid for the early universe. In fact, humans still know very little about the early universe.

4. Conclusion

In Planck gravity theory, based on cosmological principles, and based on the factors of cosmic expansion, we can derive a new coupling effect between cosmic expansion and gravity. There exists a new constant for this coupling effect, which is the coupling constant. Through this coupling effect, we can simply explain the evolution of the universe from decelerating expansion to accelerating expansion. Through calculations, we also found that this coupling effect matched well with actual cosmic measurements. So, we show that the cause of the accelerated expansion of the universe is this coupling effect. This also proves that dark energy does not exist. In other words, the essence of dark energy is this coupling effect.

Planck gravity theory is a theory of gravity that deserves in-depth study. Through this theoretical model, we find that there are still many unrevealed properties of gravity that need to be studied in depth. Gravity does not only exhibit attraction, but under special conditions, gravity can also exhibit repulsion. Regarding the universe and gravity, there are still many questions that humans need to think about and wait for humans to explore.

References

[1] A. G. Riess, et al., AJ. 116 (1998) 1009.
[2] S. Perlmutter, et al., ApJ 517 (1999) 565.
[3] Joshua A. Frieman, Michael S. Turner, Dragan Huterer arXiv:0803.0982.
[4] Xiao Lin Li, Planck Gravitation Theory, International Journal of Physics. 2019, 7(4), 118-125.
[5] Xiao Lin Li, Projection Gravitation, a Projection Force from 5-dimensional Space-time into 4-dimensional Space-time. International Journal of Physics. 2017, 5(5), 181-196.
[6] Andrew Liddle, An Introduction to Modern Cosmology, ISBN: 9781118502099.
[7] Steven Weinberg, GRAVITATION AND COSMOLOGY: PRINCIPLES AND APPLICATIONS OF THE GENERGAL THEORY OF RELATIVITY, ISBN: 0471925675.