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The Relationship between Gravitational Acceleration and the Velocity of Light

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Abstract: Based on the mass-energy equation of special relativity and the assumption of the helical motion of light speed in cosmic space, we have theoretically demonstrated the true implications of Planck's physical quantities: Planck length and time represent the step size and period of the helical motion of light speed in the earliest cosmic space following the Big Bang; Planck energy constitutes the minimum energy unit associated with this spatial helical motion; Planck mass is the mass derived from this minimum energy unit. In accordance with the expression of Planck time, we have derived the relationship formula between gravitational acceleration and the speed of light, thereby uncovering an inevitable intrinsic connection between the gravitational field and the electromagnetic field, and indicating that the four fundamental forces in the universe can be unified. Finally, through our spatial helical motion model, we computed the specific values of the four fundamental forces at the moment of strong nuclear force separation. The results reveal that they are in complete agreement with the theoretical calculation values or experimental values in modern physics and quantum mechanics, thereby providing an interesting hint for the unified field theories.

Key words: Gravitational acceleration, light-speed helical motion of space, Planck time, unified field theory, the Big Bang.

1. Introduction

Gravitational acceleration is defined as the acceleration of an object under the action of gravity, and it is typically calculated using the universal gravitational formula. The speed of light, meanwhile, represents the propagation velocity of light in a vacuum. Superficially, these two quantities appear to have no direct correlation and fall into distinct categories of physical quantities and concepts. Nevertheless, through dimensional analysis, we can derive the calculation formula for Planck time [1-4]. It reveals the unity of space-time and matter-energy, as well as the unity of quantum mechanics and relativity through the combination of the gravitational constant G, the speed of light C, and the reduced Planck constant $\hbar$, and serves as the foundation for the conversion of unit mass-energy. The relationship between gravitational acceleration and the speed of light can be directly derived from the Planck time formula. However, this derivation process is a circular proof, which leads to logical errors and invalidity. Based on the mass-energy equation of special relativity and the assumption of the helical motion of the speed of light in the earliest cosmic space of the Big Bang, we attempt to establish the relationship formula between gravitational acceleration g and the speed of light C from a strict mathematical perspective, disclose the true meaning of Planck physical quantities, and thereby identify the material and space-time basis for the unification of the four fundamental forces of the universe.

2. Planck Time

In accordance with Heisenberg's uncertainty principle [5], the product of the uncertainty in a particle's position Δx and the uncertainty in its momentum ΔP is necessarily greater than or equal to the Planck constant divided by 4π, which gives

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$$\Delta x > \frac{\hbar}{2\Delta P} = \frac{\hbar}{2mC}. \quad (1)$$

Herein, m is the mass of the particle.

According to the general theory of relativity, when the radius of the particle is smaller than the particle Schwarzschild radius R_s [6] shown as Eq. (1.1), it will turn into a black hole. Therefore, in order to prevent the from collapsing into a black hole, its radius Δx must be greater than the Schwarzschild radius R_s.

$$\Delta x > R_s = 2Gm/C^2. \quad (1.1)$$

By multiplying Eq. (1) and Eq. (1.1), we can obtain

$$\Delta x > \iota_P = \sqrt{\hbar G/C^3}. \quad (1.2)$$

The length, ι_P, is the Planck length and can also be considered as the smallest length unit in the physical sense [4]. Eq. (1.2) indicates that below the Planck length, humans have no means to detect anything, human perception of the world through the senses can only remain above the Planck length, and the spatio-temporal variations of matter are meaningless for humans. Dividing the speed of light C into Eq. (1.3) yields

$$t_P = \iota_P/C = \sqrt{\hbar G/C^5} = 5.39121 \times 10^{-44}\text{s}. \quad (1.3)$$

t_P in Eq. (1.3) is the Planck time [3], signifying the minimum interval of time quantization. No physical process can be measured or perceived within a shorter period. At the Planck time scale, the supposition of the continuity of classical spacetime becomes invalid.

3. The Hypothesis of the Light-Speed Spiral Motion in the Earliest Stage after the Big Bang

It is hypothesized that in the earliest phase after the Big Bang (within 0-n Planck times), namely, within the cosmic epoch from 0 to $n10^{-44}$ seconds, space moved in a right-handed spiral at the speed of light (see Fig. 1), expanding from zero volume to a spherical space $\boldsymbol{R}(R,\theta,\varphi)$ with a radius of R_0. The period of the moving spiral line of space $\boldsymbol{R}$ is Planck time t_P, its step length is Planck length ι_P, and its frequency is C/ι_P. Meanwhile, its polar angular coordinate φ is constantly equal to φ_0 and tends to zero [7]. Thus, in the spherical coordinate system $\boldsymbol{R}$, the radial velocity V_R, tangential velocity V_θ, and polar velocity V_φ of this spiral motion of space can be described as follows

$$V_R = \partial R/\partial t = C, \quad (1.4)$$

$$V_\theta = R_0 sin\varphi_0\, \partial\theta/\partial t = R_0 sin\varphi_0\, C/\lambda = C, \quad (1.5)$$

$$V_\varphi = R_0 cos\varphi_0\, \partial\varphi_0/\partial t = R_0\, \partial\varphi_0/\partial t = 0. \quad (1.6)$$

As depicted in Fig. 1, if a person M, who fluctuates along with space, is taken as the origin of the observer's coordinate system, the observer will observe that the universe space at this moment is moving away from us in a left-handed light-speed cylindrical helix. The period of the light-speed helical motion of space at this instant is $t_P \sim 10^{-44}$s, its frequency is ω equaling $1/t_P \sim 10^{44}$Hz, and its step length is ι_P shown as Eq. (1.7).

$$\lambda = \iota_P = Ct_P \sim 10^{-35}\text{ m}. \quad (1.7)$$

From Eq. (1.5), we can obtain that $R_0 = \lambda/\sin\varphi_0 \gg \lambda$. Since the tangential motion velocity V_θ of space pertains to the actual motion velocity of matter and cannot exceed the speed of light, the angular frequency ω_P and the tangential rotational linear velocity V_θ of the space helical motion can be expressed as

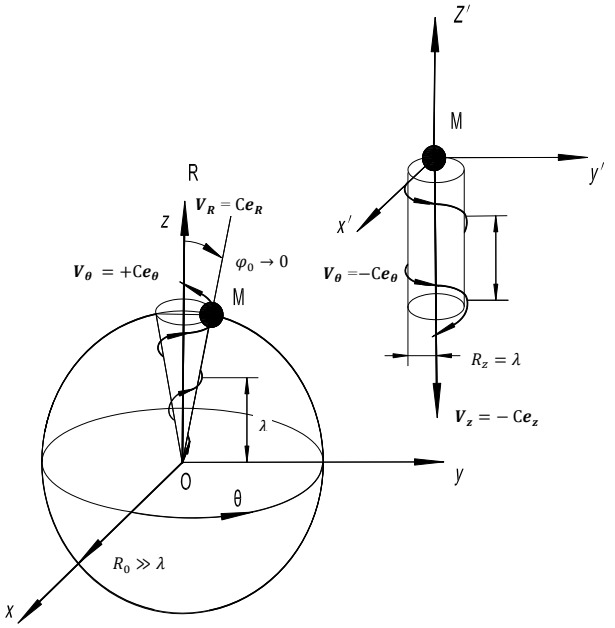

Fig. 1 The helical motion of space $\boldsymbol{R}$ during the early stage of the universal Big Bang.

$$\omega_{\mathrm{P}} = 2\pi\omega = 2\pi\,\mathrm{C}/\lambda = \mathrm{C}/\lambda \sim 10^{43}\ \mathrm{rad/s}, \quad (1.8)$$

$$V_\theta = R_z\omega = R_z/t_P = R_z\mathrm{C}/\lambda = \mathrm{C}. \quad (2)$$

Based on Eq. (2), it can be obtained that

$$R_z = \lambda = \iota_P = \mathrm{C}t_P \sim 10^{-35}\ \mathrm{m}. \quad (3)$$

4. The Formula for the Relationship between Gravitational Acceleration and the Speed of Light

During the expansion process of space $\boldsymbol{R}$ in the earliest phase of the Big Bang, the four fundamental forces of the chaotic universe were unified into the nuclear force [8]. Meanwhile, one Planck energy (the minimum energy unit of the helical motion of the light speed of space $\boldsymbol{R}$, i.e., $\hbar\omega_{\mathrm{P}}$), E_P, was transformed into one Planck mass m_P. The period of one step length λ of it is the Planck time t_P. Thus, in combination with Eq. (1.7), the time derivative of energy E in space $\boldsymbol{R}$ can be expressed as

$$\frac{dE}{dt} = E_P/t_P = \hbar\omega_{\mathrm{P}}/t_P = \hbar 2\pi\omega/t_P = \hbar\,\mathrm{C}/\lambda t_P = \hbar/t_P^2. \quad (4)$$

It can be derived from Eqs. (4) and (1.3) that

$$E_P = t_P\,\hbar/t_P^2 = \hbar/t_P = \sqrt{\hbar\mathrm{C}^5/\mathrm{G}}. \quad (4.1)$$

Eq. (4.1) is the formula for the Planck energy E_P, which possesses a distinct physical significance: the minimum energy unit $\hbar\omega_{\mathrm{P}}$ of the helically spatial motion. According to Jiang and Zhang [7], mass is generated by the light-speed helical motion of space; thus, mass is also fluctuating, and its fluctuation frequency is the same as that of the space. By integrating Eq. (4.1) and the mass-energy equation of special relativity [9], it can be obtained

$$\frac{\partial m}{\partial t} = -\mathrm{j}\omega m = m_P/t_P = \frac{1}{\mathrm{C}^2}\frac{dE}{dt} = \frac{1}{\mathrm{C}^2}\frac{E_P}{t_P} = \mathrm{C}^3/\mathrm{G}, \quad (5)$$

which gives that

$$m_P = \sqrt{\hbar\mathrm{C}/\mathrm{G}}. \quad (6)$$

In conclusion, Eq. (1.3) indicates that the Planck time t_P is the period of the light-speed helical motion of space at the earliest stage of the Big Bang, which is the reciprocal of the frequency of the helically spatial motion at that instant. Eq. (4.1) reveals that the Planck energy E_P is the minimum energy unit $\hbar\omega_{\mathrm{P}}$ of the helical motion of space at that moment. Eq. (6) suggests that the Planck mass m_P is the mass transformed from one minimum energy unit $\hbar\omega_{\mathrm{P}}$ of the helical motion of space at that moment. The Planck time t_P discloses the unity of space-time and matter-energy; it serves as the foundation for the conversion of the smallest unit of mass-energy; it is also a witness to the evolution of matter. As time, a measure of the movement of matter and the transfer of energy, it reflects the evolution pace from microscopic quantum fluctuations to macroscopic cosmic structures. Eqs. (1.3), (4.1), and (6) manifest that the Planck physical quantities have explicit physical meanings, and they are quantitative description parameters of the light-speed helical motion of the space at the earliest stage of the Big Bang.

Deriving from Eq. (4.1) gives that

$$(\hbar/t_P)^2 = \hbar\mathrm{C}^5/\mathrm{G}. \quad (6.1)$$

In accordance with Newton's law of universal gravitation, we can derive that

$$g = \mathrm{G}\frac{M}{R^2}. \quad (6.2)$$

Herein, M is the mass of a celestial body in the universe, R is the average radius of it. g is the gravitational acceleration on its surface. By synthesizing Eq. (6.1) and Eq. (6.2), it can be derived that the relationship formula between the gravitational acceleration g on a celestial body's surface in the universe and the speed of light C is presented as follows

$$g = \frac{Mt_P^2}{\hbar R^2}\mathrm{C}^5. \quad (6.3)$$

Taking the Earth as an example gives that the relationship formula between the gravitational acceleration g on the Earth's surface and the speed of light C is presented as follows

$$\mathrm{g} = \frac{Mt_P^2}{\hbar R^2}\mathrm{C}^5 = 9.8032463\ \mathrm{m/s^2}. \quad (7)$$

Herein, the mass of the Earth M is equivalent to

5.965×10^{24} kg, the average radius of the Earth R is 6.371×10^{6} m, the Planck time t_P equals 5.39121×10^{-44} s, the reduced Planck constant $\hbar$ is 1.0546×10^{-34} kg m^2/s, the speed of light C is 2.99792458×10^{8} m/s. The relative error of the calculation result with respect to the standard value [10] is 0.03449%.

5. An Interesting Hint on Deeper Relationships of the Four Fundamental Forces

According to the mass-energy conversion equation of special relativity, during the inflationary process of the Big Bang [11], the potential energy of the singularity was continuously transformed into the kinetic energy of the radial expansion of space $\boldsymbol{R}$, while this kinetic energy was constantly converted into the matter in the earliest stage of the universe. Consequently, this kind of radially spatial motion was constantly decreasing. Supposing that approximately one second after the Big Bang inflation, it dropped from the superluminal speed [12] to C, while its corresponding expansion acceleration declined to 10^{39} m/s^2 and the strong nuclear force completed its separation from the "original single force" [8], gradually transforming energy into elementary particles, successively generating quark-antiquark pairs, gluon-antigluon pairs, and electron-positron pairs, ultimately forming a plasma known as "quark soup" [13].

At this juncture, the light-speed spiral motion of space $\boldsymbol{R}$ needed to drive the motion of massive particles in space. The tangentially spiral velocity V_θ was equivalent to the tangential spiral motion velocity of particles in space and could not exceed the speed of light [8]. Assuming that the mechanism of particles revolving around the core of radially spatial motion at this moment was consistent with that of electrons in the ground state revolving around the hydrogen nucleus [14], we could obtain:

$$V_\theta = \mathrm{C}/137. \tag{8}$$

As known from Jiang and Chen [8], the light-speed spiral motion frequency of space $\boldsymbol{R}$ at this moment was the spiral motion period τ_2 of the vacuum scalar wave, that is, $\tau_2 = {\omega_P}^{-1} = \sigma_0/\omega^2\varepsilon_0 = 0.8854\times10^{-31}$ s. Here, ω_P is the oscillation frequency of the vacuum scalar wave, $\omega\sim10^{14}$ Hz is the frequency of the source light wave generating the vacuum scalar wave, $\sigma_0\sim10^{-14}$ S/m and $\varepsilon_0 = 8.854\times10^{-12}$ F/m are the vacuum conductivity and vacuum permittivity respectively.

Consequently, the spiral motion frequency of space at this moment was

$$\omega = 1/\tau_2 = 1.129\times10^{31}\ \text{Hz},$$

and its step length was shown as

$$\lambda = \mathrm{C}\tau_2 = 2.654\times10^{-25}\ \text{m}. \tag{8.1}$$

Simultaneously, the expansion radius R_1 of space $\boldsymbol{R}$ had to reach the range of the strong nuclear force, i.e., 2×10^{-15} m [15] (see Fig. 2), and the amplitude R_z of the spiral motion of $\boldsymbol{R}$ should be equal to its step length λ. And then, we can be given that

$$R_1 = 2\times10^{-15}\ \text{m}, \tag{8.2}$$

$$R_z = 2.654\times10^{-25}\ \text{m}, \tag{8.3}$$

$$\varphi_0 = sin\varphi_0 = R_z/R_1 = 1.327\times10^{-10}\ \text{rad}. \tag{9}$$

Approximately 380,000 years after the Big Bang, the expansion velocity of space $\boldsymbol{R}$ decreased to 10^{-13} times the speed of light, namely 10^{-5} m/s. The weak nuclear force (with a magnitude of 10^{26} m/s^2) completed its separation from the "original single force". At this time, a proton captured an electron to form the first hydrogen atom, and electrically neutral gas clouds gradually started to form in the universe. Photons were freed from their confinement and began to be released, causing the universe to start emitting light and brightening up. As space $\boldsymbol{R}$ continued to expand, the temperature of the universe dropped rapidly. When it dropped to 1 billion degrees Celsius, neutrons could no longer exist freely. Under the action of the weak nuclear force, hydrogen nuclear fusion was initiated, and neutrons began to combine with hydrogen atoms to form deuterium, helium, or other light elements. Chemical elements started to form during this period, and approximately 30% of the helium abundance in the universe [16] was formed at this time.

Around 1 billion years after the Big Bang, the expansion velocity V_S of $\boldsymbol{R}$ decreased to g $\tau_2 \sim 10^{-30}$ m/s, and gravity (about $9.8\ \mathrm{m/s^2}$) completed its separation from the "original single force". At this moment, the acceleration field of the spatial expansion motion of $\boldsymbol{R}$ can be expressed as:

$$a_g = \partial V_S/\partial t = V_S/\tau_2 = g\tau_2/\tau_2 = g, \quad (9.1)$$

which means that the acceleration field of the current expansion motion of space $\boldsymbol{R}$ is the gravitational field of the Earth [7]. As time went on, under the influence of gravity, the first galaxy formed in space $\boldsymbol{R}$. Subsequently, more galaxies, stars, planets, and various other celestial bodies emerged, leading to the vast universe we observe today [17]. At this moment, in space $\boldsymbol{R}$ with a helical motion at the speed of light, the momentum and force (see Fig. 3) of an object with a mass m that only undergoes free-fall motion V_{R1} (since the size of m can be neglected compared to that of the Earth, and to simplify the model, assume its volume is zero) can be represented as

$$\boldsymbol{P} = m(C - V_{R1})\boldsymbol{e_R} + mV_\theta \boldsymbol{e_\theta}, \quad (10)$$

$$\boldsymbol{F} = \partial \boldsymbol{P}/\partial t = -mg\boldsymbol{e_R} + C\boldsymbol{e_R}\,\partial m/\partial t + V_\theta \boldsymbol{e_\theta}\,\partial m/\partial t + mV_\theta\,\partial \boldsymbol{e_\theta}/\partial t, \quad (11)$$

which gives that

$$\boldsymbol{F}/m = -g\boldsymbol{e_R} + C\boldsymbol{e_R}/\tau_2 + V_\theta \boldsymbol{e_\theta}/\tau_2 + V_\theta\,\partial \boldsymbol{e_\theta}/\partial t. \quad (12)$$

Here, $C\boldsymbol{e_R}$ represents the radial expansion velocity of $\boldsymbol{R}$; $V_\theta \boldsymbol{e_\theta}$ represents the tangential rotational linear velocity of $\boldsymbol{R}$. In the spherical coordinate $\boldsymbol{R}(R, \theta, \varphi_0)$ (see Fig. 3), $\frac{\partial \boldsymbol{e_\theta}/\partial t}{\partial \theta/\partial t} = \frac{\partial \boldsymbol{e_\theta}}{\partial \theta} = -\sin\varphi_0 \boldsymbol{e_R}$, $\partial\theta/\partial t = 2\pi\omega_P = 2\pi C/\lambda = C/\lambda = V_\theta/R_z$, thus

$$\partial \boldsymbol{e_\theta}/\partial t = -\boldsymbol{e_R}\, sin\varphi_0 V_\theta/R_z. \quad (13)$$

Substituting Eq. (13) into Eq. (12) yields

$$\boldsymbol{F}/m = \boldsymbol{e_R}\, C/\tau_2 + \boldsymbol{e_\theta}\, V_\theta/\tau_2 - \boldsymbol{e_R}\, sin\varphi_0 V_\theta^2/R_z - g\boldsymbol{e_R} = \boldsymbol{a_H} + \boldsymbol{a_{T\varphi}} + \boldsymbol{a_{TR}} + \boldsymbol{g}, \quad (14)$$

In Eq. (14), the first term C/τ_2 corresponds to the strong nuclear force field generated by the radial linear motion $C\boldsymbol{e_z}$ of $\boldsymbol{R}$, the second term V_θ/τ_2 undoubtedly represents the electromagnetic field generated by its tangential rotational motion $C\boldsymbol{e_\theta}$, the third term $\sin\varphi_0 V_\theta^2/R_z$ is the weak nuclear force field related to the cone angle φ_0 of the micro-conical helical motion of space $\boldsymbol{R}$, and the last term g represents the gravitational field of $\boldsymbol{R}$. Analyzing Eq. (14), when $\tau_2 = 0.8854 \times 10^{-31}$ s, $R_z = \lambda = 2.654 \times 10^{-25}$ m, $\varphi_0 = 1.327 \times 10^{-10}$rad, $V_\theta = C/137$, we can obtain on the Earth that strong nuclear force field : electromagnetic field : weak nuclear force field : gravitational field

$$= 10^{38} : 10^{36} : 10^{25} : 1. \quad (15)$$

Eq. (14) constitutes the renowned unified field equation. The derivation of Eq. (15) might not verify the validity of the hypothesis concerning the helical motion of space at the speed of light during the earliest stage after the Big Bang but would provide an interesting hint for the unified field theories.

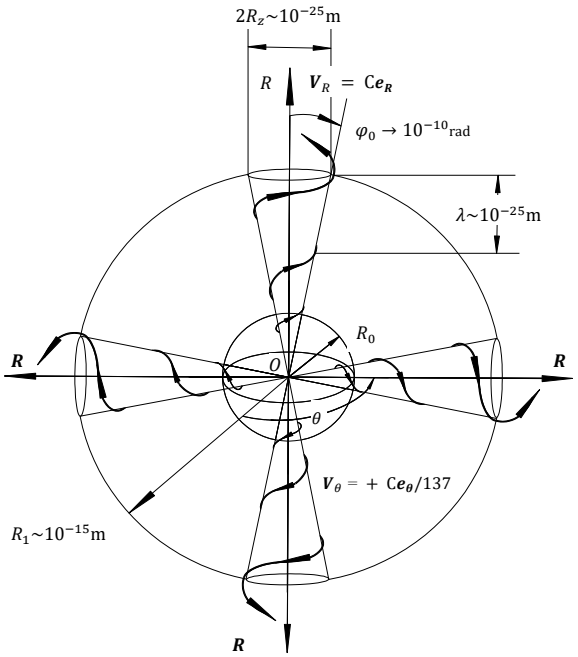

Fig. 2 The spiral motion of the space at the moment when the strong nuclear force separated.

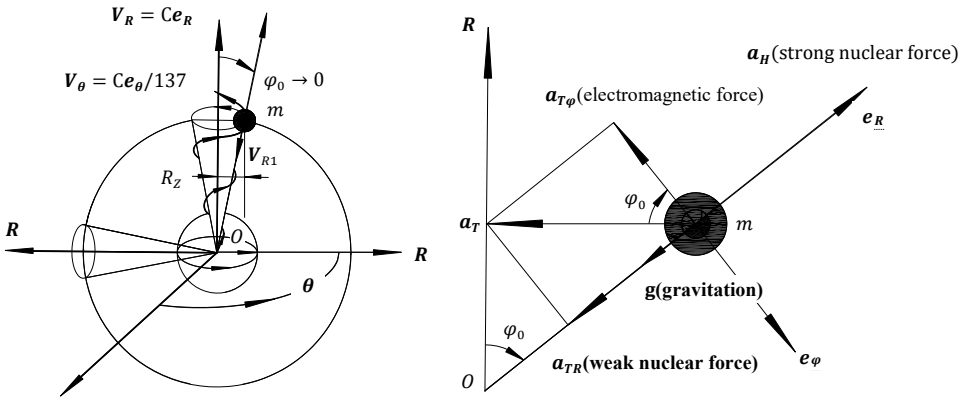

Fig. 3 Unified force fields caused by the spiral motion of our vacuum space.

6. Conclusion

Through the hypothesis of the helical motion of light speed in the space during the earliest stage after the Big Bang of the universe, we have disclosed the true meanings of the described Planck physical quantities and theoretically derived the relationship between gravitational acceleration g and the speed of light C. Herein, the Planck length is the step size of the helical motion of space in the earliest stage of the Big Bang; the Planck energy scale is the minimum energy unit $\hbar\omega_{\mathrm{P}}$ of the helical motion of space at this moment; the Planck mass is the mass transformed from the minimum unit energy $\hbar\omega_{\mathrm{P}}$ of a helical motion of space; the Planck time is the period of the helical motion of light speed in space at this moment. Through calculation, it is discovered that at the moment of the separation of the strong nuclear force, the calculated values of the four fundamental forces based on the assumption of the helical motion of light speed in space are in complete agreement with the experimental values or theoretical calculation values of modern physics and quantum mechanics, thereby providing an interesting hint for the unified field theories.

Competing interests: Authors declare that they have no competing interests.

Data and materials availability: All data are available in the main text or the supplementary materials.

Ethical approval statement: The study did not require ethical approval.

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