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Essay

Research on the Nature of Gravitational Field and the Common Laws of the Fundamental Interactions on the Basis of "Expanding Balloon" Model

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Abstract

The fundamental nature of gravitational fields and the common laws governing the four fundamental interactions remain among the most cutting-edge research challenges in physics. To address these two major scientific problems, this paper establishes a physical model of a gravitational field on the basis of an "expanding balloon" analogy. Through the study of this single model, it is deduced that a gravitational field is a form of massless, intangible, spherical field substance that extends uniformly and infinitely outward at the speed of light from the center of mass of an object with mass. This model also elucidates the physical mechanism underlying the equivalence of the gravitational mass and inertial mass. Furthermore, by simulating and analyzing a dual-model framework, the study derives key conclusions regarding the physical mechanism of gravity, the conditions for its generation, the mediator of gravitational interaction, the speed of gravitational propagation, and the mathematical formulation of the gravitational mechanism. Given that all four fundamental interactions arise from field-field interactions, further investigation not only yields mathematical expressions for the electromagnetic, strong, and weak forces but also reveals five universal laws governing all four fundamental forces: the zero-distance contact principle, the inverse-square law, the Yan Zijie's middle principle, the field divergence principle, and the field mutual noninterference principle. These principles are described using mathematical formulations.

Keywords: balloon model; zero-distance contact principle; inverse-square law; Yan Zijie's middle principle; divergence principle; mutual noninterference principle

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Introduction

For nearly a century, the grand unified theory has remained at the forefront of physics research. In the early 1920s, Einstein was awarded the Nobel Prize in Physics for his explanation of the photoelectric effect. Subsequently, he devoted himself to the study of unified field theory, aiming to establish a single theoretical framework capable of explaining both gravity and electromagnetism, the two known fundamental forces at the time. However, until his death in 1955, he was unable to complete this monumental task.[1] In the 1960s, three scientists, namely Sheldon Glashow, Steven Weinberg and Abdus Salam, proposed the electroweak unification theory, which unified the weak interaction and the electromagnetic interaction.[2,3] In the mid-1970s, based on the Yang-Mills gauge field theory, scientists established the standard model theory, thereby "unifying" three of the four fundamental interactions: electromagnetic force, strong force and weak force. However, [1]the standard model is plagued by several problems, such as the enormous discrepancies in the coupling constants of the three forces, the quark confinement problem and the mass gap problem.[4] To date, the graviton has not been detected; in fact, the standard model has not achieved the unification of all

four fundamental interactions. Subsequently, theories such as the Kaluza-Klein theory, string theory and superstring theory were put forward one after another, yet none of these theories could be empirically verified and ultimately failed to gain widespread acceptance in the physics community.[1]

In 2024, the author of this paper published a monograph titled "*Yan Huixiang's Physics View*". Building on the achievements of previous researchers, the author proposed a grand unified theory (also known as the Yan Huixiang force field theory). This theory posits that all four fundamental interactions are generated by the interactions between fields, transmitted through their respective force fields as media. These forces are all zero-distance contact forces, governed by both the zero-distance contact principle and the inverse-square law. Given the substantial differences in the coupling constants of the four forces, they are described using four separate mathematical formulas. Among these, the gravitational mechanism formula is as follows:

$$F_{\text{gravity}} = GMm / (r_1 + r_2)^2 \quad (1)$$

where F represents the gravitational force between two objects; G denotes the gravitational constant; M and m stand for the masses of the two objects respectively; and r_1 and r_2 indicate the gravitational field radii of the two objects (defined as the distance from the center of mass of one object to the intersection point of its gravitational field with that of the other object) .[5] For more than a year, the specific values of r_1 and r_2 in this formula remained undetermined. On March 30, 2025, Yan Zijie, the son of Yan Huixiang, discovered that the interaction point of the gravitational fields of the Sun and the Earth lies at the midpoint of the line connecting their centers of mass. Further research revealed that this is a universal rule in which the interaction points of the force fields corresponding to all four fundamental interactions are located at the midpoint of the line connecting the centers of mass of the two objects, which can be expressed as:

$$r_1 = r_2 = 1/2r \quad (2)$$

where r denotes the distance between the centers of mass of the two objects, representing a universal law of nature. To honor YAN Zijie's discovery, it was named the Yan Zijie's middle principle, abbreviated as the "Yan Zijie's principle" or the "middle principle". The discovery of this principle not only resolved the computational impasse of the gravitational mechanism formula but also further improved the grand unified theory.[6]

Despite the decisive progress made in the grand unified theory, the fundamental nature of gravitational fields and the question of whether interactions exist between different force fields have yet to be conclusively resolved. Through in-depth research, the author of this paper has, for the first time, constructed a physical model of the gravitational field called the "Expanding Balloon" model. By conducting simulation and deduction on the basis of this model, the author identified five common laws governing all four fundamental interactions, namely: the zero-distance contact principle, the inverse-square law, the Yan Zijie's middle principle, the field divergence principle and the field mutual noninterference principle. Among these, the field divergence principle and the field mutual noninterference principle are proposed for the first time in this paper. Consequently, the two important scientific problems mentioned above have been thoroughly resolved. This paper elaborates on and demonstrates the construction and deduction of the model, as well as the common laws of the four fundamental interactions, as detailed below:

1. The "Expanding Balloon" Gravitational Field Model:

1.1 Definition of the model: The "expanding balloon" gravitational field model refers to a physical model established on the basis that the gravitational field of a massive object is an invisible, intangible yet objectively existing spherical field matter, hereinafter referred to as the "balloon model". Definition of gravitational field: Every object with mass in nature is surrounded by an invisible, massless spherical field substance that expands uniformly outward at the speed of light in all directions from the object's center of mass. This substance, known as the gravitational field, is

physically real and, like electromagnetic fields, can be measured by instruments. The gravitational field serves as the medium through which the gravitational force is transmitted.[5,7]

In the monograph "Yan Huixiang's Physics View", the author designed a gravitational interference experiment, aiming to verify the existence of an invisible gravitational field surrounding massive objects by observing the force exerted on an object at different positions. [5] In 2018, the research team led by Academician Luo Jun from the Chinese Academy of Sciences published a paper titled "Experimental Progress in the Precision Measurement of the Gravitational Constant G" in *Acta Physica Sinica*. Using the torsion pendulum period method and torsion pendulum acceleration method respectively, the team measured the most accurate values of the gravitational constant G to be $6.674184 \times 10^{-11} \text{m}^3 / (\text{kg} \cdot \text{s}^2)$ and $6.674484 \times 10^{-11} \text{m}^3 / \text{kg} \cdot \text{s}^2$. [8] In fact, this experiment conducted by the academician Luo Jun's team can serve as evidence for the existence of an invisible gravitational field around massive objects.

1.2 Establishment of the model: In 1845, the British physicist Michael Faraday first proposed the concept of "magnetic field"; two years later, he put forward the concept of the "field" for **the first time**. [9] In 1864, the British scientist James Clerk Maxwell proposed the concept of an "electromagnetic field" and established a complete electromagnetic theory, which is described by four sets of equations. [10] In 1916, the German physicist Albert Einstein published a paper introducing the general theory of relativity, which for the first time proposed the concept of a "gravitational field" and described gravitation with a gravitational field equation. According to this theory, gravitation is not a force but a geometric effect of spacetime curvature. [11] Although this theory is the mainstream gravitational theory in the current physics community, it fails to explain the cause of spacetime curvature, in other words, Einstein did not resolve the issue of the essence of gravitation by means of the gravitational field. Nevertheless, the concept of the "gravitational field" has been accepted by the physics community and has prevailed for over a century. In 2024, on the premise of retaining the original meaning of the physics definition of the "gravitational field", the author of this paper provided a more detailed and precise redefinition of the term. While the "expanding balloon" gravitational field model was not explicitly formulated in the redefinition, this definition has in fact confirmed that the "expanding balloon" model of gravitational fields constitutes a physically valid simulation. Through deductive analysis of this model, we have uncovered the physical mechanism underlying gravity, which arises from the interaction between the gravitational fields of two massive objects, generating a zero-distance contact force directed toward each other's center of mass. This discovery has led to the formulation of a novel theory of gravitational fields. [5]

To further explore the underlying laws or resolve the issue of the essence of the gravitational field, the "expanding balloon" gravitational field model was formally proposed in this paper.

1.3 Shape of the model: By observing the radiation of light energy from a light bulb, we can find that light energy always radiates outward from the center of mass of the light source in a spherical manner, propagating at the speed of light in a vacuum. [12] Energy is a manifestation of the force state; if gravitation is described as a manifestation of the gravitational energy state, the principle of gravitational energy radiation outward is identical to that of light energy radiation. Based on the principle of light energy radiation from a light bulb, it can be inferred that the gravitational field is an invisible, massless spherical field matter that is centered at the center of mass of a massive object and extends uniformly and infinitely outward at the speed of light at all times, which is the essence of the gravitational field. Since the gravitational field propagates outward uniformly and isotropically, the shape of the gravitational field must necessarily be a standard sphere. A schematic 2D diagram of the "expanding balloon" gravitational field model is shown in Figure 1.

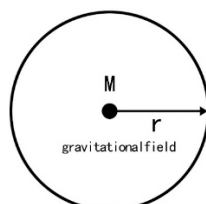


Figure 1.

2. Simulation and Deduction of the Gravitational Field Model Based on the "Expanding Balloon"

2.1. Deduction 1: Deduction of the Gravitational Field of a Single Massive Object

As shown in Figure 1, all objects consist of a physical entity and an ethereal component (gravitational field), namely: the physical entity has a mass, whereas the ethereal component (gravitational field) is massless. The ethereal component extends infinitely outward, indicating that the ethereal components (gravitational fields) of all massive objects (referring to physical entities) in nature will intersect with one another regardless of the distance between them, thus forming an integrated whole of all matter, and this is the origin of "universal gravitation".

It can also be concluded from Figure 1 that the gravitational mass of an object is equal to the sum of its physical mass and the mass of its gravitational field. Given that the mass of the gravitational field of an object is zero, the gravitational mass of an object must be equal to its inertial mass. This theoretically validates the correctness of the equivalence principle and reveals the physical mechanism underlying the equality of the gravitational mass and inertial mass. Mathematically, it can be expressed as follows:

$$m_1 = m_2 + m_3 \quad (3)$$

Since

$$m_3 = 0 \quad (4)$$

Therefore

$$m_1 = m_2 \quad (5)$$

where m_1 refers to the gravitational mass of the object, m_2 denotes the inertial mass of the object, and m_3 denotes the mass of the gravitational field of the object.[5]

2.2. Deduction 2: Deduction of the Interaction Between the Gravitational Fields of Two Massive Objects (as Shown in Figure 2)

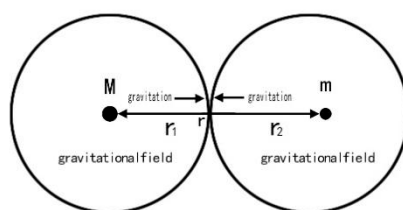


Figure 2.

At a certain moment, an object with mass M (treated as a particle) generates a gravitational field radially outward at the speed of light with its center of mass as the origin; simultaneously, another object with mass m (also treated as a particle) produces a gravitational field that propagates outward at the speed of light, centered on its own center of mass. When the gravitational fields of the two objects maintain zero distance from each other, the two intangible spherical fields collide, thereby generating gravitational force. This gravitational force then propagates toward the center of mass of each object, with the gravitational field serving as the medium of transmission. If there remains a distance between the two intangible spherical fields, they will not collide, and thus no gravitational force will be produced. Based on the above simulation and deduction, the following conclusions are drawn:

(1) Physical mechanism of gravitational force generation: The gravitational force is a zero-distance contact force directed toward each other's center of mass, arising from the interaction between the gravitational fields of two objects with mass.

(2) Necessary conditions for gravitational force generation: ① The masses of the two objects must not be zero. If either object has zero mass, it cannot generate a gravitational field, and consequently, no gravitational force will be produced; ② The distance between the gravitational fields of the two objects must be zero. If there is a distance between the two gravitational fields, they will not collide, making gravitational force generation impossible.

(3) The generation of the gravitational force follows the zero-distance contact principle, which states that the gravitational force only arises when $r=r_1+r_2$.

(4) The medium for gravitational force transmission is the gravitational field, rather than the hypothetical graviton proposed in academic circles. Gravitons do not exist.

(5) The propagation speed of the gravitational force is equal to that of the gravitational field, i.e., the speed of light in a vacuum. This conclusion can also be inferred from the principle of light energy radiation from a light bulb.

(6) The intersection point of the two gravitational fields (i.e., the gravitational interaction point) lies at the midpoint of the line connecting the centers of mass of the two objects. This is because both spherical gravitational fields propagate outward at the speed of light c over the same time interval t , which is expressed as follows:

$$r_1 = r_2 = ct = 1/2r \quad (6)$$

where r_1 denotes the radius of the gravitational field of the object with mass M ; and r_2 represents the radius of the gravitational field of the object with mass m . The gravitational field radius is defined as the distance from the center of mass of one massive object to the intersection point of its gravitational field with that of the other object. r denotes the distance between the centers of mass of the two objects. The units of r_1 , r_2 and r are all meters (m).[5]

2.3. Deduction 3: Deduction with Variations in Mass and Distance of Two Objects:

For this deduction, a torsion balance experiment can be designed for practical verification.

Experimental apparatus: 1 high-precision T-shaped torsion balance; one each of 10kg/20kg/30kg lead balls (with an accuracy of 1g), one each of 100kg/200kg/300kg lead balls (with an accuracy of 1g); a laser light source; a calibrated light screen (accuracy of up to 0.1 mm); a telescope; several fixed supports; a sealed experimental chamber; and 1 level gauge.

2.3.1. Practical Deduction with Fixed Distance and Varied Masses of Two Objects:

Experimental principle: Fix the distance r between the two objects, adjust the mass M of the larger object and the mass m of the smaller object, and measure the magnitude of the gravitational force F by the rotation angle of the torsion balance. If the ratio of the gravitational force F to the product $M \cdot m$ is a constant value, it proves that the gravitational force between the two objects is proportional to the product of their masses. The rotation angle θ of the torsion balance is in equilibrium with the gravitational torque, as expressed by the following formula:

$$k\theta = G \cdot (Mm) / r^2 \quad (7)$$

where k denotes the quartz torsion coefficient, which can be preset. The angle θ is amplified by the displacement of the reflected laser spot, thereby indirectly calculating the value of F .

Experimental procedures:

① Secure the torsion balance and the support for the large-mass object on a horizontal platform. Adjust the distance between the two objects to $r=10$ cm (measured with a caliper of 0.1 mm accuracy), ensure the alignment of the centers of mass of the two objects. Then irradiate the small mirror with the laser, adjust until the reflected light spot falls on the origin of the light screen, and record this initial position.

② Place a 10 kg small lead mass m_1 on the support, position a 100 kg large lead mass on the bracket, let the torsion balance stabilize for 30 minutes, record the light spot position, repeat the

measurement 3 times to obtain the average displacement, and calculate the gravitational force value F_1 .

③ Vary the small mass m while maintaining $M_1 = 100$ kg and $r = 10$ cm constant, sequentially replace the small lead spheres with $m_2 = 20$ kg and $m_3 = 30$ kg, and record the average spot displacement each time to calculate the corresponding gravitational force values F_2 and F_3 .

④ Vary the large mass M while maintaining $M_1 = 100$ kg and $r = 10$ cm constant, then sequentially replace the large lead spheres with $M_2 = 200$ kg and $M_3 = 300$ kg, and record the average spot displacement each time to calculate the gravitational force values F_4 and F_5 .

⑤ Select a small lead ball of 20 kg and a large lead ball of 2 kg, repeat the experiment following the aforementioned procedures, measure the value of gravitational force F_6 , and then verify whether the ratio of F_6 to $M \cdot m$ is consistent with that of the previous experimental groups.

Data analysis:

① Calculate the ratio $k' = F / (M \cdot m)$ for each experimental group. If the relative error of k' across all groups is less than 5%, the proportional relationship is preliminarily verified;

② Plot a graph with $M \cdot m$ as the abscissa and F as the ordinate. If the graph is an oblique straight line passing through the origin with a goodness-of-fit $R^2 \geq 0.99$, the conclusion that gravitational force is proportional to the product of the two objects' masses is quantitatively verified.

Error control measures:

① All lead balls used in the experiment were made of lead material with uniform density to ensure the fixed position of their centers of mass and avoid errors caused by non-particle effects.

② The temperature inside the sealed experimental chamber was controlled at 20 ± 5 °C to reduce the impact of air convection or thermal expansion and contraction of the materials.

③ After each replacement of lead balls, the torsion balance is allowed to settle for approximately 30 minutes to minimize random errors caused by instrument vibrations.

④ The light spot is observed remotely via a telescope, and under no circumstances is experimental apparatus be touched directly.

Note: The author of this paper does not have the conditions to conduct the aforementioned torsion balance experiment. Nevertheless, the torsion balance experiment conducted by Henry Cavendish in 1798 not only determined the specific value of the gravitational constant G , but also directly proved that the gravitational force between two objects is proportional to the product of their masses.[13] Similarly, the torsion balance experiment reported in the paper "*Experimental Progress in the Precise Measurement of the Gravitational Constant G* " by the research team led by Luo Jun from the Chinese Academy of Sciences in 2018,[8] also verified that the gravitational force between two objects is proportional to the product of their masses. That is:

$$F \propto M \cdot m \quad (8)$$

2.3.2. Practical Deduction with Fixed Masses and Varied Distances Between Two Objects:

Experimental principle: The gravitational force between the large lead ball with mass M and the small lead ball with mass m generates a torque, causing the quartz fiber of the torsion balance to twist. When the torsional torque balances the gravitational torque, the torsion balance comes to rest. The small mirror mounted on the torsion balance reflects the laser beam onto the light screen, where the tiny torsion angle θ is amplified into a distinct displacement of the light spot. The specific value of the torsion angle θ is calculated from the spot displacement, which is then used to derive the magnitude of the gravitational force. By altering the distance between the two objects multiple times, a comparison is made between the gravitational force and the square of the distance.

Experimental procedures:

① Fix a large lead ball with a mass of $M=300$ kg and a small lead ball with a mass of $m=30$ kg on their respective supports. The positions of the two lead balls were adjusted via a guide rail, and the initial distance between them was set as r . The system was allowed to stand undisturbed until the

torsion balance stabilized, the position of the light spot on the screen was recorded, the measurement was repeated 3 times, and the average displacement of the spot was calculated.

② Secure the torsion balance, laser light source, and light screen inside a sealed experimental chamber. The laser beam is adjusted to irradiate the small mirror on the torsion balance so that the reflected light spot falls on the center of the screen, and this initial spot position is recorded. Moreover, the guide rail is used to calibrate the setup, ensuring that the two lead balls and the torsion balance are at the same horizontal height.

③ Keep the masses of the two lead balls unchanged, and sequentially adjust the distance between them to r_n . Each distance is measured and recorded via a caliper; distance values are preferably selected within the range of 10–50 cm to avoid nonparticle effects caused by excessively short or long distances. After each distance adjustment, the average displacement of the light spot is recorded, and all observations are conducted remotely via a telescope to prevent experimental interference.

④ Calibrate the torsion balance in advance, apply a known horizontal force directed toward the large lead ball at the position of the small lead ball, record the relationship between the light spot displacement and the corresponding torque, and establish a conversion formula between the spot displacement and the magnitude of the gravitational force.

Data analysis:

① Based on the calibration formula, the light spot displacement obtained from each experiment is converted into the corresponding gravitational force values $F_1, F_2, F_3 \dots F_n$.

② Calculate the ratio of the gravitational force F to $1/r^2$ for each dataset. If the ratios derived from multiple datasets are approximately constant, it can be preliminarily concluded that the magnitude of gravitational force is inversely proportional to the square of the distance.

③ A graph with $1/r^2$ as the abscissa and F as the ordinate is plotted. If the graph shows an oblique straight line passing through the origin, it confirms that the magnitude of the gravitational force is inversely proportional to the square of the distance.

Error control measures: Maintain a constant temperature inside the experimental chamber to prevent air convection; use quartz fibers instead of ordinary metal wires to reduce the impact of torsional damping; select regular, uniform spheres for both the large and small lead balls to approximate them as point masses; and perform multiple measurements for each dataset to reduce accidental errors.

Note: The author of this paper also lacks the conditions to conduct this torsion balance experiment. In 2018, the School of Physics of Huazhong University of Science and Technology and the Tianqin Center for Gravitational Physics of Sun Yat-sen University jointly published a paper titled "Experimental Progress in Testing the Newtonian Inverse-Square Law at Short Distances" in *Acta Physica Sinica*. This paper reported a high-precision experimental test of the Newtonian inverse-square law at short distances using state-of-the-art equipment internationally at that time, and the results showed that the Newtonian inverse-square law withstood rigorous experimental verification. [14] From the above experiments, the conclusion can be drawn that the magnitude of the gravitational force between two objects is inversely proportional to the square of the sum of the radii of their gravitational fields. That is:

$$F \propto 1/(r_1+r_2)^2 \quad (9)$$

2.3.3. Mathematical Expression of Gravitational Force:

Based on the conclusion from Section 2.3.1 that $F \propto M.m$, and the conclusion from Section 2.3.2 that $F \propto 1/(r_1+r_2)^2$, the gravitational constant G is introduced to derive the mathematical expression of gravitational force:

$$F_{\text{gravity}} = GMm/(r_1+r_2)^2 \quad (1)$$

This mathematical expression describes the physical mechanism of gravitational force generation: the gravitational force arises from the interaction between the gravitational fields of two massive objects. Hence, it can also be referred to as the gravitational mechanism formula, where F indicates the gravitational force between the two objects, a vector quantity with the unit of Newton (N); G denotes the gravitational constant, approximately $6.67 \times 10^{-11} \text{m}^3/\text{kg} \cdot \text{s}^2$; M and m symbolize the masses of the two objects, with the unit of kilogram (kg); and r_1 and r_2 denote the gravitational field radii of the two objects, with the unit of meter (m). [5]

3. Common Laws Governing the Four Fundamental Forces:

The preceding section presents practical simulations and deductions based on the "expanding balloon" gravitational field model, yielding a series of regular conclusions including the physical mechanism of gravitational force generation and its mathematical expression. On the basis of the fundamental principle that all four fundamental interactions arise from field-field interactions sharing identical operational mechanisms, further in-depth research reveals that these forces obey additional universal governing laws.

3.1. Zero-Distance Contact Principle:

Definition: The force field between objects in nature can only produce force when the interaction maintains zero distance contact, which is called the zero distance contact principle.[5]

As indicated in Conclusion 3 of the deduction in Section 2.2, gravitational force is generated only if the gravitational fields (intangible spherical field substances) of two massive objects maintain zero distance from each other, which is expressed as: $r=r_1+r_2$, where r denotes the distance between the centers of mass of the two objects, and r_1 and r_2 indicate the gravitational field radii of the two objects respectively.

Since "field-field interaction is the essence of force generation", in addition to gravitational force, the other three known fundamental forces, including the electromagnetic force, strong force, and weak force, also obey the zero distance contact principle. The relationship between their respective force fields also satisfies $r=r_1+r_2$. Therefore, the mathematical expression of the zero distance contact principle is as follows:

$$r=r_1+r_2 \quad (10)$$

In the preceding Section 1.3, on the basis of the principle of light energy radiation from light bulbs, it is inferred that gravitational fields are intangible, massless, spherical field substances that extend infinitely outward at the speed of light. Given that all four fundamental forces conform to the zero distance contact principle, it can be deduced that the force fields corresponding to electromagnetic force, strong force, and weak force are also intangible, massless, spherical field substances propagating infinitely outward at the speed of light.

Previously, the academic community has long held that forces are transmitted through the exchange of gauge bosons. For example, virtual photons are considered the mediators of electromagnetic force; gluons mediate strong force; and W and Z bosons serve as the mediators of weak force. [15]However, particles can never achieve zero-distance contact regardless of proximity, there is always a finite separation between them. If particles remain spatially separated, forces cannot be directly transmitted. This would require an additional mediating medium, yet no such extrinsic medium exists in reality. According to quantum field theory, particles are simply quantized excitations of their underlying fields, with each particle type corresponding to its own unique field.[16]Furthermore, Conclusion 4 of the deduction in Section 2.2 confirms that the medium of the gravitational force is the gravitational field. Only field-field interactions can achieve zero distance, thereby enabling force transmission.

Logically speaking, the traditional academic view that "particles act as the mediators of force transmission" is incorrect. The only valid mediators of force are the fields excited by particles, specifically, the mediator of electromagnetic force is not the "virtual photon", but the electromagnetic

field excited by photons; virtual photons do not exist. (Virtual photons are hypothetical particles in academia and are not included in the Standard Model. Although theoretical value of the "electron anomalous magnetic moment" calculated on the basis of virtual photon exchange matches the experimental value with a precision of up to 12 decimal places,[17,18] this may be attributed to misinterpretation of experimental results by researchers.) The mediator of strong force is not the gluon, but the gluon-excited field, referred to as the gluon gauge field. The mediator of weak force is not the W and Z bosons, but the W and Z boson-excited fields, referred to as the W and Z gauge fields.[5]

3.2. Mathematical Expressions of the Four Fundamental Forces:

Given that all four fundamental forces originate from field-field interactions and share the same physical mechanism of force generation, the gravitational mechanism formula was derived through deduction in Section 2.3.3 as follows:

$$F_{\text{gravity}} = G M m / (r_1 + r_2)^2 \quad (1)$$

On this basis, the mathematical expression of the electromagnetic force is inferred as:

$$F_{\text{electromagnetic}} = K q_1 q_2 / (r_1 + r_2)^2 \quad (11)$$

where $F_{\text{electromagnetic}}$ denotes the electromagnetic force between two point charges, a vector quantity with the unit of Newton (N); q_1 and q_2 represent the electric charges of the particles, with the unit of Coulomb (C); r_1 refers to the radius of the electromagnetic field of q_1 , and r_2 is the radius of the electromagnetic field of q_2 , both in meters (m); and K denotes the Coulomb constant, $k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2$. The electromagnetic field radius is defined as the distance from the center of the electromagnetic field of one charge (coinciding with the charge's center of mass) to the interaction point (also referred to as the intersection point) with the electromagnetic field of the other charge.

The mathematical expression of the strong force is given by:

$$F_{\text{strong}} = Q q_1 q_2 / (r_1 + r_2)^2 \quad (12)$$

The F_{strong} is the interaction force between two particles, and is a vector with the unit of N; q_1 and q_2 denote the chromatic charges of two particles, with units of chromatic charge; r_1 indicates the radius of the gluon gauge field (excited by gluons) of q_1 , and r_2 is the radius of the gluon gauge field of q_2 , both in meters (m); and Q denotes the strong interaction constant (to be measured). The gluon gauge field radius is defined as the distance from the center of the gluon gauge field of one charge (coinciding with the charge's center of mass) to the interaction point (also referred to as the intersection point) with the gluon gauge field of the other charge.

The mathematical expression of the weak force is expressed as:

$$F_{\text{weak}} = R q_1 q_2 / (r_1 + r_2)^2 \quad (13)$$

The F_{weak} is the weak interaction between two particles, represented as a vector with the unit N; q_1 and q_2 denote the weak charges of two particles, with each unit being a weak charge; r_1 indicates the radius of the W and Z gauge fields (excited by W and Z bosons) of q_1 , and r_2 is the radius of the W and Z gauge fields of q_2 , both in meters (m); R denotes the weak interaction constant (to be measured). The W and Z gauge field radius is defined as the distance from the center of the W and Z gauge fields of one charge (coinciding with the charge's center of mass) to the interaction point (also referred to as the intersection point) with the W and Z gauge fields of the other charge.[5]

3.3. The Inverse-Square Law:

Definition: It refers to the fact that the strength of an object or particle's interaction linearly decays with the square of the distance, that is, the interaction force is inversely proportional to the square of the distance.[19]

According to the "expanding balloon" gravitational field model, an object consists of a tangible entity and an intangible component (gravitational field). In three-dimensional space, the gravitational

field generated by a point mass source radiates uniformly outward in all directions at the speed of light. Its gravitational flux Φ (referring to energy or interaction strength) is distributed on a spherical surface centered at the point source. Since the surface area of a sphere is proportional to the square of its radius, i.e., $S \propto r^2$, the intensity of the gravitational field is thus inversely proportional to the square of the radius of the field sphere, expressed as: $E_{\text{field intensity}} \propto 1/r^2$.

Mathematical deduction: Based on the conservation of field flux,[20] the following equation holds:

$$\Phi = E_{\text{field intensity}} \cdot S \quad (14)$$

where Φ denotes the gravitational flux, $E_{\text{field intensity}}$ indicates the intensity of the gravitational field, and S represents the surface area of the gravitational field sphere with radius r .

$$S = 4\pi r^2 \quad (15)$$

Substituting equation (15) into equation (14), we obtain:

$$E_{\text{field intensity}} = \Phi / 4\pi r^2 \quad (16)$$

That is:

$$E_{\text{field intensity}} \propto 1/r^2 \quad (17)$$

Experimental verification:

Through the torsion balance experiment described in Section 2.3.2 above, the gravitational forces between two lead balls at different distances were measured, leading to the conclusion that $F \propto 1/(r_1+r_2)^2$. Given that $r = r_1+r_2$, the relationship can be simplified to:

$$F \propto 1/r^2 \quad (18)$$

$$F = E_{\text{field intensity}} m \quad (19)$$

Therefore:

$$E_{\text{field intensity}} \propto 1/r^2 \quad (17)$$

Since all four fundamental forces originate from field-field interactions and share the same physical mechanism, and the intensity of the gravitational field is inversely proportional to the square of the radius of the field sphere, the force fields corresponding to the other three fundamental forces also follow the relationship $E_{\text{field intensity}} \propto 1/r^2$. In other words, all four fundamental forces comply with the inverse-square law.

3.4. Yan Zijie's Middle Principle:

Definition: The points of action of the four fundamental forces in nature (gravity, electromagnetic force, strong force, and weak force) are all located in the middle position of the line connecting the two object points. This principle of nature is called "Yan Zijie's middle principle", abbreviated as "Yan Zijie's principle", or "middle principle". This principle is one of the most common principles in nature.

As indicated in Conclusion 6 of the deduction in Section 2.2 above, the intersection point of the gravitational fields of two objects (i.e., the gravitational interaction point) lies at the midpoint of the line connecting their centers of mass. The mathematical expression of this principle is:

$$r_1 = r_2 = 1/2r \quad (6)$$

where r_1 and r_2 denote the gravitational field radii of the two objects, and r indicates the distance between the centers of mass of the two objects.

The principles of the four basic forces are the same, and they are all generated by the interaction between force fields. Based on this, it can be inferred that the force-field interaction points of the electromagnetic force, strong force, and weak force is also located in the middle of the line connecting the particle points of the two objects. That is, $1/2r$.

The discovery and demonstration processes of this middle principle are not elaborated herein; for details, please refer to the paper "A Study on the Unified Law Governing the Force Field Interaction Points of the Four Fundamental Forces — Yan Zijie's principle".[6]

3.5. Field Divergence Principle:

Definition: The force fields corresponding to the four fundamental forces in nature (gravitational force, electromagnetic force, strong force, and weak force) all take the center of mass of an object as the origin, and extend uniformly and infinitely outward at the speed of light at all times. This natural principle is named the field divergence principle, referred to as the "divergence principle". It is also one of the most universal principles in nature.

Force field definition: A force field is a vector field in which the vector associated with each point can be measured by a force. [21]A force field is invisible and intangible. It is a special form of real matter. Gravitational fields, electromagnetic fields, and gauge fields constitute fundamental force fields. The force field is also the medium for transmitting the four fundamental forces. The gravitational field is the medium for transmitting gravity, the electromagnetic field is the medium for transmitting electromagnetic force, the gluon gauge field (the field generated by gluon excitation) is the medium for transmitting strong force, and the W and Z gauge fields (the fields generated by W and Z boson excitation) are the media for transmitting weak force.[5]

Given that the "expanding balloon" gravitational field model is a spherical model radiating outward from a point source, which is characterized by "propagation at the speed of light", and that the four fundamental forces share the same generation mechanism, the force field models corresponding to the other three forces (electromagnetic force, strong force, and weak force) are also spherical models radiating outward from a point source, with the same attribute of "propagation at the speed of light". Accordingly, the mathematical expression of the "field divergence principle" can be deduced as follows:

$$r(t)=ct \quad (20)$$

where r denotes the radius of the spherical field matter, with the unit of meter (m); c indicates the speed of light in vacuum, i.e., 299792458 m/s; and t represents the time elapsed for the spherical field matter to extend outward from the center of mass, with the unit of second (s).

Mathematical deduction:

A Cartesian coordinate system (x,y,z) is employed for the description, with the center of mass fixed at the origin $O(0,0,0)$ (as shown in the figure). The radial spherical coordinate radius r is defined as follows:

$$r=\sqrt{x^2+y^2+z^2} \quad (21)$$

At the initial moment $t=0$, the radius of the spherical field matter is $r_0=0$, indicating that the field starts to extend outward from the center of the point mass.

The propagation speed is the speed of light c in vacuum, and the radial extension is uniform. Therefore, the radius r of the spherical field matter at any arbitrary moment t satisfies the following:

$$r(t)=r_0+ct \quad (22)$$

Substituting

$$r_0=0 \quad (23)$$

Then

$$r(t)=ct \quad (20)$$

By combining equations (20) and (21), we obtain:

$$\sqrt{x^2+y^2+z^2}=ct \quad (24)$$

That is, the boundary points of the field matter in any radial direction of the spherical field satisfy Equation (24), which may be referred to as the field boundary motion equation, where x , y , and z represent the 3D coordinates of any arbitrary point on the surface of the spherical field matter; c denotes the speed of light in vacuum; and t indicates the time elapsed for the spherical field matter to extend outward from the center of mass.

Since the spherical field matter has no rest mass, its material distribution on the spherical surface can be characterized by the energy-momentum tensor $T^{\mu\nu}$. Under the condition of spherical symmetry, $T^{\mu\nu}$ only has diagonal components:

where $\rho(r, t)$ represents the energy density, i.e., the energy per unit volume; $E_r(r, t)$ represents the radial field intensity under spherical symmetry, with the tangential field intensities satisfying $E_\theta = E_\phi = 0$.

The uniform outward extension of the spherical field matter implies that the surface energy density σ (i.e., energy per unit area) of the spherical field matter at a given moment is constant:

At any arbitrary moment t , the surface area S of the spherical boundary of the field matter is given by:

$$S(t) = 4\pi r^2(t) = 4\pi c^2 t^2 \quad (25)$$

Rearranging the equation yields:

$$c = \sqrt{S/4\pi} \times 1/t \quad (26)$$

Let E denote the total energy of the spherical field matter. Given that the spherical field matter has no rest mass, then

$$E = pc \quad (27)$$

where p denotes the total momentum, and c represents the speed of light in a vacuum.

Substituting Equation (26) into (27) yields the functional relationship between total energy E and time t as:

$$E = p \sqrt{S/4\pi} \times 1/t \quad (28)$$

Since the spherical field matter extends infinitely outward at the speed of light, the radial velocity v_r of any arbitrary point on the spherical field matter is:

$$v_r = dr/dt \quad (29)$$

\rightarrow In spherical coordinates, the velocity vector is expressed as: $\vec{v} = (c, 0, 0)$.

The differential equation governing the outward extension of the spherical field matter is derived as follows:

The propagation speed c is the first-order derivative of the sphere radius with respect to time:

$$c = dr/dt \quad (30)$$

The extension acceleration a is the second-order derivative of the sphere radius with respect to time. As the extension is uniform, the acceleration is zero, i.e.:

$$a = d^2r/dt^2 = 0 \quad (31)$$

The field matter of the spherical body exhibits negligible thickness during extension, with energy distribution confined exclusively to the boundary. The spatial energy density $\rho(r, t)$ therefore satisfies a delta-function distribution, meaning that energy exists solely at the light-cone boundary $r = ct$. Thus:

$$\rho(r, t) = \frac{E(t)}{4\pi r^2(t) dr} = \frac{\sigma}{dr} \Delta(r - ct) \quad (32)$$

where Δ denotes the Dirac delta function, characterizing energy concentration strictly at the boundary, which is consistent with the outward-extending geometric feature from the center of mass.

As $t \rightarrow \infty$:

① The radius $r(t)$ of the spherical field matter diverges $r(t) \rightarrow \infty$, indicating infinite extension;

② When the surface mass density σ remains constant, the spatial energy density $q(r, t)$ behaves as follows:

$$q(r, t) \propto \frac{1}{r^2} \Delta(r-ct) \rightarrow 0 \quad (33)$$

3.6. Principle of Field Mutual Noninterference

Definition: The force fields corresponding to the four fundamental forces in nature (gravitational force, electromagnetic force, strong force, and weak force) all propagate outward at the speed of light with point sources as their centers. When fields of the same type meet, they generate interactions; when fields of different types meet, no interaction occurs. This natural principle is named the principle of field mutual noninterference, referred to as the principle of mutual noninterference. It is also one of the most universal principles in nature.

The principle of field mutual noninterference is determined by two core properties: mutual noninterference of fields and independent propagation of fields:

① **Mutual noninterference of fields:** The force fields of the four fundamental forces, once excited from their point sources, propagate outward at the speed of light. Only when fields of the same type encounter each other do they generate a force interaction, which then propagates toward each other's center of mass with the respective force field as the medium. No interaction occurs when fields of different types meet. Regardless of whether the encountering fields are of the same or different types, they can pass through the overlapping region unimpeded and continue propagating in their pre-encounter state. Their physical properties (e.g., spherical shape) remain unchanged by the presence of other fields.

② **Independent propagation of fields:** When the force fields of the four fundamental forces propagate in space, their key parameters (e.g., propagation direction and propagation speed) are not affected by other fields, whether those fields are of the same type or different types. Even when multiple fields overlap, each field can pass through the others smoothly and continue advancing without any influence.

To verify the validity of the principle of field mutual noninterference, the method of proof by contradiction can be adopted.

① **The four coupling constants corresponding to the four fundamental forces are fixed constant values, which can prove the validity of the principle of field mutual noninterference.** If this principle did not hold, i.e., interactions could occur between fields of different types, then in cosmic space where various fields often overlap in the same spatial region the four coupling constants of the fundamental forces would not remain fixed, but instead vary with the field distribution. This is clearly inconsistent with the observational data.

② **Only if the principle of field mutual noninterference holds can all celestial and terrestrial objects maintain stable operation.** If the principle of mutual noninterference between fields does not hold, meaning different types of fields can interact with each other, for example, when a massive object emits a spherical gravitational field propagating outward at the speed of light from its center of mass, while simultaneously a point charge emits a spherical electromagnetic field that also propagates at the speed of light from its center, and if these two distinct fields were to intersect and generate a new "force" interaction mediated by their respective fields, propagating back toward each other's center of mass, then this "force" would necessarily constitute a fifth fundamental force beyond the four currently known ones. Moreover, there might even exist a sixth, seventh, or more such force. However, this scenario clearly contradicts established physical reality. Regardless of what this hypothetical "force" might be called, its existence would cause universal chaos: no object on Earth would obey Newton's law of universal gravitation or Coulomb's law, the stable orbits of the solar system would collapse, and even the coherent structure of the Milky Way and the entire universe would instantly unravel.

Therefore, based on the two points above, the principle of field mutual noninterference is theoretically valid without doubt.

Mathematical expressions:

This paper only studies the laws governing the force fields of the four fundamental forces (i.e., gravitational field, electromagnetic field, and strong/weak interaction fields). The principle of field mutual noninterference is described below in the forms of a functional expression, an integral expression, and a simplified expression, respectively:

① Functional expression: Let two fields with different properties be denoted as F_i and F_j , and their corresponding Lagrangian density of field interaction be $\text{Lint}(F_i, F_j)$. Then the functional expression of the principle of field mutual noninterference is given by:

$$\text{Lint}(F_i, F_j) = 0 \quad (i \neq j) \quad (34)$$

$$\text{Lint}(F_i, F_j) \neq 0 \quad (i = j) \quad (35)$$

where F_i, F_j generally refers to any physical field (gravitational field, electromagnetic field, strong/weak interaction fields); and i and j represent field type identifiers. If the identifiers are different, the fields are defined as heterogeneous fields; if the identifiers are the same, the fields are defined as homogeneous fields. $\text{Lint}(F_i, F_j)$ represents the Lagrangian density of the interaction between field F_i and field F_j .

② Integral expression: Assume that field F_i satisfies the gauge condition $G_i(F_i) = 0$, field F_j satisfies the gauge condition $G_j(F_j) = 0$, and their coupling constants satisfy $g_i \neq g_j$ (i.e., heterogeneous fields). The the integral expression of the principle of field mutual noninterference is given by:

$$\int \text{Lint}(F_i, F_j) d^3x = 0 \quad (i \neq j, G_i \neq G_j, g_i \neq g_j) \quad (36)$$

$$\int \text{Lint}(F_i, F_j) d^3x = \text{Sint}(F_i) \neq 0 \quad (i = j, G_i = G_j, g_i = g_j) \quad (37)$$

where $d^3x = dx^1 dx^2 dx^3$ is the volume element of three-dimensional space, and the integral represents the total interaction action $\text{Sint}(F_i)$ of the fields.

③ Simplified expression: This simplified expression is described in terms of field intensity. Suppose any physical field F can be characterized by its field intensity E , or in the form of a tensor—for example, the gravitational field is described by the metric tensor $g_{\mu\nu}$. In addition, each type of field corresponds to a unique gauge condition $G(F) = 0$. Let E_i denote the field intensity of field F_i , and E_j represent the field intensity of field F_j , then the simplified expression of the principle of field mutual noninterference is given by:

$$E_i \cdot E_j = 0 \quad (i \neq j) \quad (38)$$

$$E_i \cdot E_j = |E_i| \cdot |E_j| \cos\theta \neq 0 \quad (i = j) \quad (39)$$

where θ represents the angle between the field strengths of the same type of field.

Mathematical deduction:

The necessary and sufficient condition for the existence of a direct interaction between two fields F_i and F_j is that the interaction Lagrangian density $\text{Lint}(F_i, F_j)$ of the two fields is non-zero, and the corresponding total interaction action $\text{Sint}(F_i) = \int \text{Lint}(F_i, F_j) d^3x$ satisfies the principle of variation, namely: $\delta \text{Sint} \neq 0$.

Let F_i and F_j be two arbitrary physical fields. If F_i and F_j are homogeneous fields, they satisfy the same gauge condition:

$$G_i(F_i) = G_j(F_j) = G(F) \quad (40)$$

The coupling constants are also equal:

$$g_i = g_j = g \quad (41)$$

If F_i and F_j are heterogeneous fields, their gauge conditions are different:

$$G_i(F_i) \neq G_j(F_j) \quad (42)$$

The coupling constants are also unequal:

$$g_i \neq g_j \quad (43)$$

Suppose that F_i (with gauge G_i and coupling constant g_i) and F_j (with gauge G_j and coupling constant g_j) are heterogeneous fields. If a direct interaction exists between these two fields, their interaction Lagrangian density must satisfy the gauge conditions of both fields simultaneously:

$$\text{Lint}(F_i, F_j) \propto g_i g_j G_i(F_i) G_j(F_j) \quad (44)$$

Since $G_i(F_i)$ and $G_j(F_j)$ are two mutually independent gauge constraints, the gauge conditions of heterogeneous fields have no intersection, and the coupling constants g_i and g_j of the two fields are irrelevant. This leads to:

$$G_i(F_i) G_j(F_j) = 0 \quad (45)$$

Thus, the interaction Lagrangian density of two heterogeneous fields is:

$$\text{Lint}(F_i, F_j) = 0 \quad (i \neq j) \quad (34)$$

By integrating over the three-dimensional space, the total interaction action can be obtained as follows:

$$\text{Sint}(F_i, F_j) = \int \text{Lint}(F_i, F_j) d^3x = 0 \quad (i \neq j) \quad (46)$$

Conclusion: There is no direct interaction between heterogeneous fields.

If F_i and F_j are two homogeneous fields, i.e., $F_i = F_j = F$, the interaction Lagrangian density of the two fields only needs to satisfy a single gauge condition, and the coupling constant term satisfies $g^2 \neq 0$. Therefore:

$$\text{Lint}(F, F) \propto g^2 G(F) G(F) \neq 0 \quad (47)$$

The total interaction action is as follows:

$$\text{Sint}(F, F) = \int \text{Lint}(F, F) d^3x \neq 0 \quad (48)$$

Conclusion: An interaction is present between homogeneous fields (consistent with empirical facts).

4. Conclusion:

Through the deductive study of the "expanding balloon" physical model of gravitational fields, this paper not only uncovers the fundamental nature of gravitational fields but also elucidates the physical mechanism behind the equivalence between the gravitational mass and inertial mass. Furthermore, it derives mathematical expressions for all four fundamental forces and establishes five universal principles along with their corresponding mathematical formulas that govern these interactions. These systematic findings demonstrate that the author has achieved a coherent, self-consistent theoretical framework in exploring the nature of forces (the four known types) and fields, representing a significant milestone in theoretical physics. The proposed theories are bound to have profound implications across physics, astronomy and cosmology.

5. Outlook: Following the proposal of these theories, experimental physicists may now design experiments to verify their validity. While this paper has primarily focused on simulating a physical model with two "expanding balloons," theoretical physicists could extend this work to systems of three, four, or even more balloons, potentially yielding further discoveries. Additionally, the novel theoretical framework presented herein could be applied to explain established physical phenomena such as Mercury's perihelion precession. In essence, both experimental and theoretical physicists now possess abundant new research opportunities, heralding a period of vigorous development in the field of physics. Crucially, as all conclusions in this work are derived through rigorous deductive reasoning rather than speculative hypotheses, they carry exceptionally high credibility. This finding necessitates the cessation of current quantum gravity research predicated solely on mathematical models by a significant segment of academic physicists, as the demonstrated mechanism of gravity

generation through the interaction of dual "gravitational field balloons" fundamentally precludes the possibility of gravitational quantization.

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