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Classical Unification of Gravitational and Electromagnetic Forces

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Abstract: We have presented a theory of unification of gravitational force and the electromagnetic force by generalizing Newton's law of gravitation to include a dynamic term similar to the Lorentz force of electromagnetic interaction. The inclusion of this dynamic term alone in the gravitational force is enough to develop the entire dynamic theory of gravitation parallel to that of electrodynamics. The theory naturally solves the mystery of action-at-distance. It has been shown that the inverse square law of the static and the dynamic forces is the result of the conservation of mass (Gauss's Law) and the total momentum (Wang's Law). The Wang's Law is a new discovery. The new theory also predicts that the gravitational wave is propagated at the speed of light.

Keywords: *Unification of gravitational, Electromagnetic forces, Gravitation, Electrodynamics, General relativity and Theory-of-everything.*

Abbreviations: *TOE-Theory of Everything, GUT-Grand Unified Theory, LQG-Loop Quantum Gravity and LQC-Loop Quantum Cosmology*

1. Introduction

Since Maxwell unified the theory of electricity and magnetism, the unification of gravitational and electromagnetic fields had become the dream of the physics community. Early attempts were made by Hermann Weyl, Arthur Eddington, Theodor Kaluza and Albert Einstein.

Hermann Weyl's theory of infinitesimal geometry was based on general relativity [1]. He believed that in addition to a metric field there could be additional degrees of freedom along a path between two points in a manifold. He introduced a gauge field as basic method for comparison of local size measures along such a path. It generalized Riemannian geometry in that there was a vector field Q in addition to the metric g. The vector field and the metric together generated both the electromagnetic and gravitational fields. This theory was mathematically complicated, resulting in high-order field equations. Weyl and his colleagues worked out the mathematical ingredients of the theory. Weyl's theory was found physically unreasonable after communication with Einstein and others. But Weyl's principle of gauge invariance was later applied to quantum field theory.

Kaluza's approach of unification was to embed space-time into a five-dimensional cylindrical world, consisting of four space dimensions and one time dimension. The extra dimension allowed the electromagnetic field vector to be incorporated into the geometry. After discussion with Einstein it was discovered that Kaluza's theory did not allow a non-singular, static, spherically symmetric solution, a critical test of the validity of the theory [2, 3].

Sir Arthur Eddington proposed an extension of the gravitational theory based on the affine connection as the fundamental structure of the gravitational field, instead of the metric tensor as the fundamental structure according to general relativity [4]. Eddington believed that the stress–energy tensor in Einstein's field equations was provisional, and that in a unified theory the source term would automatically come up from the field equations. Eddington's theory were sketchy and difficult to understand. Very few physicists followed up on his work.

Einstein considered the electromagnetic field energy being equivalent to mass according to his mass-energy relationship $E=mc^2$, and contributes to the stress tensor and to the curvature of space-time. Namely, certain configurations of curved space-time should incorporate effects of an electromagnetic field. Einstein then treated both the metric tensor and the affine connection as fundamental fields. His unified-field equations were derived from a variational principle expressed in terms of the Riemann curvature tensor for the presumed space-time manifold [5].

However, Riemannian geometry is unable to describe the properties of the electromagnetic field as a purely geometric phenomenon. The abstract nature and the lack of mathematical tools for analyzing nonlinear equations made it hard to connect such a theory with the physical reality. Einstein became isolated from physics community since then, and his attempts to unify gravity with electromagnetic field were not successful. The unification theories of Einstein and his contemporaries are considered "classical unification theories". These theories were built around Einstein's general relativity with different ways of modification, all met with failure. After the 1930s, few scientists worked on classical unification, partially due to the failure of Einstein and others' theories, partially due to the emergence of quantum field theory.

The unification of electromagnetic interaction with the weak nuclear interaction under the framework of the Standard Model seems to be encouraging, and many are hoping that the further development of quantum field theory might eventually lead to the unification with the strong nuclear interaction and the gravitational interaction in a final Theory-of-Everything (TOE). In 1961, American physicist Sheldon Glashow proposed that the weak force and the electromagnetic force can be cast into a unified electro-weak theory [6]. In 1967, Pakistan physicist Abdus Salam and American physicist Steven Weinberg independently modified Glashow's theory to obtain the masses of W and Z particles from a Higgs field through symmetry breaking [7-9]. In such electro-week theory, the electromagnetic interaction is propagated through photon; the week interaction is propagated through three particles: a neutral Z particle and two W particles. In 1983, the Italian physicist Carlo Rubbia's group at CERN declared that he found the Z and W particles. Rubbia and Simon van der Meer shared the 1984 Nobel Prize in physics. Later on, Gerardus 't Hoot proved that the Glashow-Salam-Weinberg model was mathematically self-consistent (renormalizable). The electro-week theory thus was accepted by theoretical physics community as the Standard Model [10].

Unification of the strong interaction within the framework of the Standard Model seems to be the next logical step. The effort in this direction, however, has not been very successful. Sheldon Glashow and Howard George proposed in 1974 a model to include the strong interaction into the electro-week theory, known as the Goerge-Glashow model [11]. It was the first Grand Unified Theory (GUT). The major problem with GUT is that the energy needed to check these theories is in the order of 10^{16} GeV, way beyond what the current technology could reach. It means that the accelerator needs to be bigger than the solar system. It is absolutely impossible.

A theory not experimentally verifiable and falsifiable cannot be considered a scientific theory. Another problem with the GUT is contradiction between its predictions and experimental findings. For instance, many GUT theories predict that the proton would decay, but the experiments show that the lifetime of the proton is at least 10^{35} years, which is more than 20 orders of magnitude longer than the theoretical prediction of the lifetime of the Big Bang universe. Proton does not decay in fact. It is a heavy blow on the effort to unify the strong nuclear force along the approach of quantum field theory represented by the Standard Model. The unification of gravitational force with other fundamental forces is even harder. An unsurmountable

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obstacle is that the gravitational field is not renormalizable, which means that a unification theory including the gravitational force in the framework of the Standard Model would be a divergent theory. Any divergent theory does not make any physical sense. It is now generally realized that general relativity is incompatible with quantum field theory. From the point of view of energy scale, Theory of Everything requires an energy scale of the Planck energy of 10^{19} GeV. That is 1000 times higher than the energy scale of the Grand Unification Theory. It is far beyond the reach of the modern accelerator.

In spite of all these difficulties, some theorists are exploring approaches toward unified field theory beyond the standard quantum field theory. The two important directions are the super string theory and the Loop Quantum Gravity (LQG). In 1980s, Green and Schwarz proposed a revolutionary "superstring theory" which attracted much attention of physics community [12]. "Superstring theory" needs ten dimensions to work, with 6 "extra dimensions" "curled up" into strings wrapped up on the scale of the Planck length. Such a theory is also known as "theory of everything" because it might be a candidate to unify all the fundamental forces. The superstring theory is frustratingly abstract which is hard to be related to physical reality. No one could even explain the physical meaning of the extra dimensions. The super string theories are so abstract that the theorists could not identify any physical quantity for the experimental physicists to verify. Namely, the super string theories are quite irrelevant to our physical world. A Nobel laureate (1999), Martinus Veltman, made a concluding remark in his book **"Facts and Mysteries in Elementary Particle Physics":** "The reader may ask why in this book string theory and super symmetry have not been discussed……The fact is that this book is about physics, and this implies that the theoretical ideas discussed must be supported by experimental facts. Neither super symmetry nor string theory satisfies this criterion. They are figments of the theoretical mind. To quote Pauli: they are not even wrong." [13]. Another big issue with the superstring theory is that at least five competing superstring theories have been proposed to compete each other. The embarrassing trouble seemed to be alleviated in 1995 when Whitten conjectured that five different versions of string theory might be different presentation of the same theory if the eleventh dimension is introduced [14]. With the eleventh dimension added, the "string" becomes "membrane". The "superstring theory" evolves into a "membrane theory", or "M-theory", the complete structure of which has yet to be discovered. The M-theory is compatible with the concept of multiverse. In such a theory, a Big Bang is caused by chance collisions between rippling membranes, and our universe came from a Big Bang which was just one of the many collisions between membranes. The "chance collisions", or parallel universes, might be infinite in number. Such a theory of "creation by chance collision between infinitely many membranes" seems to conjure away the inconvenient and intractable questions of "how was our universe created" and "what was it like before the creation".

The M-Theory is not the only proposal for a "theory of everything". A "Loop Quantum Gravity" (LQG) was developed by Ashtekar, Ling, Smolin, Rovelli, Thiemann and others [15-19]. In LQG the space-time is fundamentally discrete and quantized. Space can be viewed as a network of finite loops called "spin networks", having the size of Planck length (about 10^{-35} m). The Loop Quantum Cosmology (LQC) studies the early universe and the physics of the Big Bang. According to such study, the Big Bang was the consequence of the last Big Crunch. The terminal Big Bang is replaced by a picture of Big Bounce similar to the picture of oscillating universe. Both the M-theory and Loop quantum gravity have their fundamental issues to solve before being accepted into the main stream standard model. For M-theory, the extra dimensions have no empirical support and physical meaning. No physical quantity that is experimentally verifiable has been predicted by the theory. As to the Loop quantum gravity, the proposition of discrete space-time is quite radical. The unification of gravitational force with other forces is a failure along either the approach of general relativity or the approach of quantum field theory. It is fair to say that the chances for unifying gravitation with other forces under the framework of Standard Model or general relativity are extremely slim.

1.1. Generalization of Newton's Theory of Gravitation

Instead of trying to unify all forces, we have recently developed a theory to unify the gravitational force with the electromagnetic force strictly within the classical framework [20, 21]. In this review article we will only present the basic framework and the major results of this unification theory without details. The rigorous mathematical proof of the equations and Wang's Law can be found in references [20, 21]. We hope to present our work against the historical background to show better the position and significance of our effort in the context of hundred year's long dream of physics community to unify the gravitational and the electromagnetic forces. The major difference between references [20, 21] is that in reference [20] we leave the speed of gravitation open to be determined by experimental measurement, while in reference [21] the speed of gravitational wave is speculated equal to the speed of light based on the identity of the field equations and the wave equations. The option of reference [20] can be called "soft generalization" while that of reference [21] "strong generalization". The prediction of strong generalization is to be verified experimentally. The endeavor in this direction is under way.

1.2. We are Inspired by Two Observations:

- Newton's law of gravitation is strikingly similar to Coulomb's law.

Newton's law differs strikingly from Coulomb's law by lacking a dynamic term dependent on the velocity of the gravitating source. As a result, Newton's law is essentially a static theory unable to describe the propagation of the gravitational force, which is the theoretical origin of the problem of action-at-distance.

We can ask a natural question: Is the lacking of a dynamic term in Newton's law a true manifestation of the law of Nature, or a theoretical miss due to the weakness of the dynamic part of the gravitational force that escaped the detection by astronomers and physicists? If the latter is the case, what kind of dynamic term should be added to Newton's law?

Let us try to answer the first question by examining the Lorentz force [21]:

$$\mathbf{F} = k_1 \frac{qq'}{r^2}\left[\hat{\mathbf{r}} + \frac{1}{c^2}\mathbf{v}'\times\left(\mathbf{v}\times\hat{\mathbf{r}}\right)\right] \qquad (1)$$

Where k_1 is the Coulomb constant, c the speed of light, q and q' the charges, r the distance between them, r is the displacement vector running from q to q', $\hat{\mathbf{r}}$ is the unit vector of r. v and v' are the velocities of the two charges q and q', respectively. The first term of Equation (1) is the Coulomb force while the second term is the magnetic force that can be found in decent textbooks such as Classical Electrodynamics by J.D. Jackson. In the most favorable case, the second term (dynamic term) is weaker than the first term (static term) by a factor of (vv'/c^2). If the gravitational force also includes a similar dynamic term, it will be weaker than the static term by the same factor. The orbital velocity v' of the earth is about 30 km/s, and the velocity v of the sun about the center of mass of the solar system is about 0.1 m/s. These values would give the factor of (vv'/c^2) in the order of 10^{-13}. That is to say, the dynamic term, if exists, would cause a difference of less than a factor of 10^{-13} in the gravitational force between the sun and the planets. It is definitely beyond the ability of the observational astronomers to detect.

Although the dynamic term has little effects on the orbital movements of the planets, it is a necessity to describe the propagation of the gravitational wave and answer the question of action-at-distance. If we are to add a dynamic term to Newton's law of gravitation, what kind of form would such dynamic term take? Well, it is all too natural to speculate that the dynamic term should take the same form of the Lorentz force considering the striking similarity between Newton's law of gravitation and Coulomb's law. In the following sections, we will present a generalized theory of gravitation by adding a dynamic term similar to the Lorentz force:

$$\mathbf{F} = -G\frac{mm'}{r^2}\left[\hat{\mathbf{r}} + \frac{1}{c^2}\mathbf{v}'\times\left(\mathbf{v}\times\hat{\mathbf{r}}\right)\right], \quad (2)$$

where $\hat{\mathbf{r}}$ is the unit vector of the displacement vector r running from m to m', r the distance, v and v' the velocities of the two masses m and m', respectively.
The first term of the gravitational force is static:

$$\mathbf{F}_1 = -G\frac{mm'}{r^2}\hat{\mathbf{r}}\ . \quad (3)$$

We can define a static field:

$$\mathbf{g} = \frac{\mathbf{F}_1}{m'} = -G\frac{m}{r^2}\hat{\mathbf{r}}\ . \quad (4)$$

The second term can be written as

$$\mathbf{F}_2 = -G\frac{mm'}{r^2}\frac{1}{c^2}\mathbf{v}'\times\left(\mathbf{v}\times\hat{\mathbf{r}}\right) = -G\frac{mm'}{r^2}\left[\left(\boldsymbol{\beta}'\cdot\hat{\mathbf{r}}\right)\boldsymbol{\beta} - \left(\boldsymbol{\beta}'\cdot\boldsymbol{\beta}\right)\hat{\mathbf{r}}\right] = \mathbf{M}\cdot m'\boldsymbol{\beta}', \quad (5)$$

where β and β' are the ratios of velocities over the speed of light, M is a second rank anti-symmetric tensor constructed by the usual rule of dyadic of two vectors:

$$\mathbf{M} = \frac{Gm}{cr^3}\left(\hat{\mathbf{r}}\mathbf{v} - \mathbf{v}\hat{\mathbf{r}}\right) = \frac{Gm}{cr^3}\begin{pmatrix} 0 & v_y x - v_x y & v_z x - v_x z \\ v_x y - v_y x & 0 & v_z y - v_y z \\ v_x z - v_z x & v_y z - v_z y & 0 \end{pmatrix}. \quad (6)$$

Since the angular momentum

$$\mathbf{L} = \mathbf{r}\times\mathbf{p} = m\mathbf{r}\times\mathbf{v}\ , \quad (7)$$

We have

$$\mathbf{M} = \frac{G}{cr^3}\begin{pmatrix} 0 & L_z & -L_y \\ -L_z & 0 & L_x \\ L_y & -L_x & 0 \end{pmatrix}. \quad (8)$$

Define a vector **d**:

$$\mathbf{d} = \frac{G}{cr^3}\mathbf{L} = \frac{G}{cr^2}\hat{\mathbf{r}}\times\mathbf{v}, \quad (9)$$

We have

$$\mathbf{M} = \begin{pmatrix} 0 & d_z & -d_y \\ -d_z & 0 & d_x \\ d_y & -d_x & 0 \end{pmatrix}. \quad (10)$$

Apparently, the vector d is proportional to the angular momentum L of the moving mass about the point of interest and inversely proportional to the cube of the distance r. Since L is proportional to r, Equations (8) and (9) manifest inverse square law of d and M. d is called the dynamic field, and M the dynamic field tensor.
The gravitational force can be expressed as

$$\mathbf{F} = m'\left[\mathbf{g} + \mathbf{M}\cdot\boldsymbol{\beta}'\right] = m'\left[\mathbf{g} + \boldsymbol{\beta}'\times\mathbf{d}\right]. \quad (11)$$

The total gravitational field f is defined as the total gravitational force per unit mass:

$$\mathbf{f} = \mathbf{g} + \mathbf{M}\cdot\boldsymbol{\beta}' = \mathbf{g} + \boldsymbol{\beta}'\times\mathbf{d}. \quad (12)$$

1.3. Gauss' Law and Wang's Law
It can be shown that [20]

$$\nabla\cdot\mathbf{g} = -4\pi G\rho, \quad (13)$$

where,

$$\rho = \frac{dm}{dV} \quad (14)$$

is the local mass density, V the volume.
The similar closed surface integral of the dynamic field tensor M is [20]

$$\oiint_s \mathbf{M}\cdot d\boldsymbol{\sigma} = -\frac{8\pi Gm}{3c}\begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} = -\frac{8\pi G}{3c}m\mathbf{v} = -\frac{8\pi G}{3c}\mathbf{p}, \quad (15)$$

Where, $\mathbf{p} = m\mathbf{v}$ is the linear momentum of the gravitating mass. Equation (13) is Gauss' law. Equation (15) is Wang's Law, which says that the closed integration of the dynamic field tensor M is a constant proportional to the linear momentum of the moving mass. Wang's law is therefore a statement that the total linear momentum transmitted through the gravitational field into the space is conserved. The constant $-4\pi GM$ in Gauss' law is called the total static flux.

The constant $\frac{-8\pi G}{3c}m\mathbf{v}$ is called the total dynamic flux. We can then speak of conservation of the total static and dynamic fluxes of the gravitational field.

The conservation of the total static flux and the dynamic flux reveals how the gravitational interaction is transmitted. A mass m at rest in space causes stress to the medium ether. If the mass is at rest the total stress flux is equal to $-4\pi GM$. If the mass is moving with velocity v, it will cause additional dynamic stress to the ether. The momentum-induced stress will then propagate into the space, with the total linear momentum constant and distributed over the total solid angle. The static and the dynamic fields are simply the stress fluxes per unit area and therefore inversely proportional to the distance squared. It naturally explains the inverse square law of the electromagnetic and the gravitational forces.

The significance of this discovery can be appreciated if we recall the history of the discovery of inverse square law. Newton discovered that in order to explain Kepler's third law, his newly proposed law of gravitation must be inversely proportional to the square of the distance. The power index 2 was pretty much a result of fitting the data since Kepler's laws ware all results of empirical observation. People can always ask if the index is exactly or approximately equal to two. As a matter of fact, some theoretical textbooks actually give a derivation of the inverse square law along this thread of thinking. Coulomb's law and Biot-Savart law are also empirical laws. Empirical laws are always subject to experimental errors. The issue is finally settled by Gauss' law and Wang's law. The inverse square law is as exact as the surface area of a sphere is equal to the radius squared.

1.4. The Wave Equation of Gravitational Field

It can be shown that [20]

$$\nabla\cdot\mathbf{f} = -4\pi G\left(\rho + \frac{2}{3c}\boldsymbol{\beta}'\cdot\mathbf{j}\right), \qquad (16)$$

$$\nabla\cdot\mathbf{d} = 0, \qquad (17)$$

$$\nabla\times\mathbf{d} = \frac{1}{c}\frac{\partial\mathbf{g}}{\partial t} + \frac{8\pi G}{3c}\mathbf{j}, \qquad (18)$$

$$\nabla\times\mathbf{f} = -\frac{1}{c}\frac{\partial\mathbf{d}}{\partial t}, \qquad (19)$$

Where,

$$\mathbf{j} = \rho\mathbf{v} = \frac{\mathbf{p}}{V} \qquad (20)$$

is the momentum density, i.e., the momentum per unit volume. $\mathbf{p}$ is the total momentum of the mass contained in the volume V. $\mathbf{j}$ is also the current density (Current per unit area).

Equations (16)-(19) constitute a set of fundamental equations of the gravitational field. In a free space where $\rho = 0$ and $\mathbf{j} = 0$, these equations take simple and symmetric form:

$$\nabla\cdot\mathbf{f} = 0, \qquad (21)$$

$$\nabla\cdot\mathbf{d} = 0, \qquad (22)$$

$$\nabla\times\mathbf{d} = \frac{1}{c}\frac{\partial\mathbf{f}}{\partial t}, \qquad (23)$$

$$\nabla\times\mathbf{f} = -\frac{1}{c}\frac{\partial\mathbf{d}}{\partial t}. \qquad (24)$$

Equations (21)-(24) constitute a complete set of equations that describe the propagation of the gravitational wave in vacuum. Routine manipulation of these equations yields a wave equation:

$$\nabla^2\mathbf{f} - \frac{1}{c^2}\frac{\partial^2\mathbf{f}}{\partial t^2} = 0 \qquad (25)$$

with solution

$$\mathbf{f} = \mathbf{f}_0\sin\left(\omega t - \mathbf{k}\cdot\mathbf{r}\right), \qquad (26)$$

where

$$\omega = 2\pi\nu = \frac{2\pi}{T} \qquad (27)$$

is the angular frequency. ν and T are the frequency and the period. $\mathbf{k} = k\hat{\mathbf{k}}$ is the wave number:

$$k = \frac{2\pi}{\lambda}, \qquad (28)$$

and

$$\lambda = cT \quad (29)$$

is the wavelength. c is the speed of light.
A similar procedure yields a wave function for **d**:

$$\mathbf{d} = \mathbf{d}_0 \sin(\omega t - \mathbf{k} \cdot \mathbf{r}). \quad (30)$$

2. Discussion

It is generally believed that general relativity predicted the gravitational wave. The matter of fact is, the wave equation is not derived from general relativity but manufactured based on a number of invalid hypotheses, starting with linear approximation of Einstein's field equation.

Einstein's field equation is given by Kenyon [22]

$$G_{\beta\delta} = \frac{8\pi G T_{\beta\delta}}{c^4} + \Lambda g_{\beta\delta}. \quad (31)$$

Or, alternatively [22]

$$R_{\beta\delta} = \frac{8\pi G\left(T_{\beta\delta} - T_\mu^\mu g_{\beta\delta}/2\right)}{c^4} - \Lambda g_{\beta\delta}. \quad (32)$$

A number of hypotheses are postulated:

i) The first hypothesis: The space is supposed to be vacuum so the stress-energy tensor $T_{\beta\delta} = 0$.

ii) The second hypothesis: The cosmological constant is zero: $\Lambda = 0$.

With these two hypotheses, the field equation reduces to

$$G_{\beta\delta} = R_{\beta\delta} = 0. \quad (33)$$

iii) The third hypothesis: The field is week and the metric tensor can be approximated as nearly Minkowski:

$$g_{\beta\delta} = \eta_{\beta\delta} + h_{\beta\delta}, \quad (34)$$

Where $h_{\beta\delta}$ is infinitesimal compared to $\eta_{\beta\delta}$. Under such linear approximation, Equation (33) reduces to

$$R_{\beta\delta} = \frac{1}{2} g^{\alpha\nu}\left(h_{\nu\delta,\beta\alpha} - h_{\delta\beta,\nu\alpha} + h_{\alpha\beta,\nu\delta} - h_{\alpha\nu,\beta\delta}\right) = 0. \quad (35)$$

Or,

$$h_{\nu\delta,\beta\alpha} - h_{\delta\beta,\nu\alpha} + h_{\alpha\beta,\nu\delta} - h_{\alpha\nu,\beta\delta} = 0. \quad (36)$$

iv) The fourth hypothesis: To solve Equation (36), it is assumed that each term in the equation is separately zero, which leads to Kenyon [22]:

$$h^\alpha_{\beta\delta,\alpha} = 0, \quad (37)$$

$$h^\alpha_\alpha = 0, \quad (38)$$

$$h^\alpha_{\delta,\alpha} = h^\alpha_{\alpha\beta,} = 0, \quad (39)$$

$$h_{\alpha 0} = 0. \quad (40)$$

Equation (37) is the familiar form of wave equation:

$$\frac{\partial^2 h_{\beta\delta}}{\partial x^2} + \frac{\partial^2 h_{\beta\delta}}{\partial y^2} + \frac{\partial^2 h_{\beta\delta}}{\partial z^2} - \frac{\partial^2 h_{\beta\delta}}{c^2 \partial t^2} = 0. \quad (41)$$

Let us examine the four hypotheses for yielding the wave equation (41). The first hypothesis is in direct conflict with the mainstream cosmology, which stipulates that the universe is filled with the dark matter that is supposed to be 30 times more than the "ordinary matter". It is therefore not justified to assume zero stress-energy tensor. The second hypothesis assumes the cosmological term to be zero, in direct conflict with the current mainstream cosmology that claims that the cosmological constant counts for up 68% of the total matter of the universe. The third hypothesis is invalid near the black holes because that is where the metric tensor diverges to infinity, not anything close to Minkowski metric. The fourth hypothesis cannot be justified mathematically. No mathematician would assume individual terms of an equation to be separately zero in order to solve the equation.

It is very clear that the gravitational wave equation is not "derived" from Einstein's general relativity, but manufactured with a number of invalid hypotheses. The true derivation of gravitational wave equation was given by our unification theory published in 2018 [20, 21].

Our unification theory predicts that the gravitational interaction is propagated by gravitational wave with the speed of light. The existence of gravitational wave is now a common knowledge, and is a solid experimental evidence of our unification theory. As discussed above, gravitational wave equation is not derived from general relativity, but manufactured with a few invalid hypotheses. Einstein at most speculated the gravitational wave without a rigorous proof. Our unification theory has truly derived, first time ever, the gravitational wave equation without any approximation or ad hoc hypothesis.

Besides experimental evidence of gravitational wave, our unification theory has made a number of predictions (not hindsight confirmations) to be verified by experimental physicists: 1) The speed of gravitational wave is the same as the speed of light. 2) The dynamic component of the gravitational force between the sun and the planets is weaker than the static component by a factor of 10^{-13}. With the modern technology, it is possible to pursue experimental detection of the dynamic gravitational force if the project is properly funded. 3) The total linear momentum propagated into the whole space is conserved (Wang's Law). Since this is a new discovery based on the unified theory of gravitational and electromagnetic forces, it can be verified or falsified with electromagnetic wave.

Historically, "a gravitational equivalent of the magnetic force has been speculated by Lorrain and Corson in 1970, making a statement that such force "could only be attractive" without any quantitative analysis. Salisbury and Menzel also speculated the similar force-which they called a "Gyron Field"-with a brief quantitative analysis based on a particular example of two stationary mass/charges whose gravitational attraction exactly balances their electrostatic repulsion [22, 23]. Salisbury and Menzel result based on this special arrangement concluded a repulsion force, contradicting Lorrain and Corson's conclusion. Quantitatively, Salisbury and Menzel yielded a result different from an earlier work of Sciama [24].

Ohanian and Ruffini also arrived at a force similar to the Lorentz force of electromagnetism based on linear approximation of general relativity [25] under the assumptions:

$$u^0 \approx 1; u^k \approx v^k \neq 0 \quad (42)$$

They yielded an approximate equation of motion: (Reference 26, chapter 3, Equations 3-96):

$$\frac{du_\mu}{d\tau} + \kappa\left(h_{\mu 0,l} - h_{0l,\mu}\right)v^l - \frac{\kappa}{2}h_{00,\mu} = 0 \quad (43)$$

Define

$$f_{\alpha\beta} = \frac{\kappa}{2}\left(h_{\mu 0,\alpha} - h_{0\alpha,\beta}\right) \quad (44)$$

$f_{\alpha\beta}$ is not a second rank tensor, but a particular 0-components of a third-rank tensor, which can be expressed in the matrix form:

$$f_{\alpha\beta} = \begin{pmatrix} 0 & g_x & g_y & g_z \\ -g_x & 0 & -\frac{b_z}{2} & \frac{b_y}{2} \\ -g_y & \frac{b_z}{2} & 0 & -\frac{b_x}{2} \\ -g_z & -\frac{b_y}{2} & \frac{b_x}{2} & 0 \end{pmatrix} \quad (45)$$

Where, $g_x = f_{01} = -\left(\frac{\kappa}{2}\right)h_{00,1}, b_x = 2f_{32} = \kappa\left(h_{02,3} - h_{03,2}\right)$ and so on. In terms of vectors **g** and **b**, Equation (45) can be cast into a vector form:

$$\frac{d\mathbf{v}}{dt} = \mathbf{g} + \mathbf{v}\times\mathbf{b} \quad (46)$$

Which is Equation (3-100) of reference [26] analogous to the Lorentz force of electrodynamics.

Although Ohanian and Ruffini managed to come up with something similar to the Lorentz force, its validity depends on a number of approximation assumptions under weak field condition, and on the validity of the fundamental postulations upon which the fundamental field equation (43) is built. To prove that Equation (43) is generally valid, it must be shown that it is valid not only for particular 0-components of a third-rank tensor $f_{\alpha\beta}$, but also valid for all other components of the tensor $h_{\alpha\beta,l}$, which the author failed to do. The linear field approximation speaks nothing about the rest components of the tensor equation. The authors then compared g and b to the electric and magnetic field in Maxwell's electrodynamics and asserted that g and b must satisfy equations analogous to Maxwell equations:

$$\nabla\times\mathbf{g} + \frac{1}{2}\frac{\partial\mathbf{b}}{\partial t} = 0 \quad (47)$$

$$\nabla\times\mathbf{b} = -16\pi G\cdot\mathbf{S} \quad (48)$$

where **S** is the momentum density. Equation (47) and (48) look similar to our equation (19) and (18), but essentially different in that Equation (47) does not include a time derivative of **g** which are vitally important for yielding a wave equation. Even for the term involving the the momentum density **S** the coefficient is different from ours that are derived directly from the force law, instead of simply being "recognized" based on the analogy with Maxwell equations. The authors also failed to develop further and obtain the field equations and the wave equations. The equations (43), (46), (47) and (48), which are Equations (3.96), (3.100), (3.103) and (3.107) [26] are not more illuminating than the previous attempts.

There are other works on the theory of gravitation "beyond" Newton's framework. For example, Wang XS tried to "derive" Newton's inverse square law of gravitation based on a fluid continuum model of vacuum and a sink flow model of particles [26]. This work presented a different way from Newton's original approach based on Kepler's three laws without providing any new insight into the essence of gravitation and any new info about the dynamic aspect of gravity, let along gravitational wave equation. The concept of "continuum of vacuum" and "sink flow of particles" remain mystery, as we know that gravity propagates through vacuum.

The earlier speculations show that the generalization of Newton's law of gravitation to include a dynamic term is a very natural and logical attempt to develop a more general theory of gravitation. The earlier attempts with simple and special models have also demonstrated the extreme challenges facing physicists to develop a logically consistent and systematic general theory of gravitation with mathematical rigor and completeness. Our unification theory of gravitational and electromagnetic forces has answered the historical call by providing a rigorous derivation without any ad hoc hypothesis of a systematic and complete theory with a set of field equations and wave equation.

The readers would probably ask a natural question at this point: Can the nuclear forces be included in the classical theory of unification considering the success of the new unification theory? Can we follow your classical approach to find a Theory-of-Everything?

Nothing is philosophically wrong with trying to unify all the forces we know presently, but such unification has to be done naturally. We can unite the forces only if these forces are amenable to unification. We have to wait till we have a good understanding of the nuclear force. So far we don't even have a formula of the nuclear force as a function of the distance between the nucleons and their velocities. We do not have a nuclear force law. The most reasonable speculation of the nuclear force law up to now is the Yukawa potential, but it is a static force without a dynamic term, and it is purely theoretical speculation. There is no direct experimental measurement to verify the correctness and accuracy of Yukawa potential. We do not know if Yukawa potential applies to strong nuclear interaction.

It might sound surprising. The scientists have been studying nuclear interactions for a whole century, with history-making achievements such as nuclear bombs and nuclear reactors. Enormous amount of data of particle collisions have been

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accumulated in the past few decades. Are these data not enough for us to say that we know the nuclear force very well? Not really. The modern experiments in particle physics are prescribed by theorists based on various hypotheses. The processes from the interactors to the final products usually involve many stages following many possible branches. The experiments are rather indirect. The results in many cases are subject to interpretation. The evaluation of the results can be very subjective and biased. The results not confirming the expectation of a prevailing theory are dismissed as negative and failure. The detection of God particle is a good example. The electron-positron collider (LEP) in CERN spent about ten years searching for the God particle in the 1990s. They found nothing. Fermi Lab searched for the God particle from 1995 to 2011. They found nothing. Both of these experiments were considered failures because they did not support the Standard Model. In 2015, the LHC group announced that they found something around 125 GeV that might be a God particle. It was immediately welcomed and endorsed by the theoretical community as a positive result. From experimental point of view, the negative results of LEP in CERN and the Fermi Lab should have equal statistical weight as the positive result of LHC. But such is not the culture of the particle physics community.

The negative results that do not confirm predictions of the Standard Model would be considered failures. Only positive results confirming the Standard Model would be considered successes. If the LHC result were negative, it would have been dismissed as another failure, and the process of verification would continue until some positive results show up and confirm the theory. Repeating the experiment means further investment of another billion dollars and ten years of hard work of thousands of researchers. Funding may be granted for repetition only when the previous results are negative. The tradition of biased evaluation discourages publication of non-confirming results, which further establishes the authority of a theory, and the vicious cycle sustains. With all these biased efforts, we still do not see an accepted formula of the nuclear force as a function of distance and the velocities of the nucleons.

Another evidence of our lack of understanding of nuclear interaction is the historical division of nuclear force into two forces – the weak force and the strong force. Enrico Fermi tried to apply the methodology of quantum electrodynamics to study nuclear reactions based on his proposed Lagrangian.

2.1. His Trial Theory Ran into Two Problems

- The energy was not conserved.
- It worked only for slow nuclear decay reactions, but failed for the rapid nuclear reactions.

There were two solutions to the first problem. Wolfgang Pauli proposed a new particle neutrino to carry the missing energy; Niels Bohr proposed a way without neutrino. Fermi adopted Pauli's proposition. The second problem has no easy solution. Theorists had to either abandon Fermi's theory altogether, or retain his theory as a partial theory applicable to the slow nuclear reaction only. It is an apparent indication that Fermi's theory was at most approximately correct. With Fermi's fame and authority, it is not likely that his theory would by totally abandoned considering his unchallengeable position as the father of atomic energy and a giant in theoretical physics. Theorists then declared that there were two fundamentally different nuclear forces: the weak force and the strong force, and Fermi's theory applies to the weak interaction only.

Dividing nuclear interaction into two fundamentally different interactions based on the speed of interaction is by no means convincing. For example. Oxidation can be very slow to cause rusting of metals, or cause violent combustion or explosion. Namely, the same oxidation reaction can be very slow and very fast. Chemists do not claim that there are two fundamentally different reactions of oxidation. The division of nuclear interaction into two fundamentally different interactions is merely a manifestation that we do not know nuclear force very well. Suppose someday the physics community has found the nuclear force law as a function of distance and velocity, we can then try to unify it with the gravitational and electromagnetic forces. However, the unification has to be natural. We cannot and will not manufacture a "unification theory" by piling up a dozen hypotheses in N-dimensional extra dimensions with two dozens of free parameters. We would rather have separate descriptions of different forces without fundamental inconsistencies than a "unified theory" with infinities and two dozens of free fitting parameters and extra dimensions. Unification is a dream, not a mandate. Even if some day we successfully unified the nuclear force, we will not pursue a "Theory of Everything".

2.2. The Idea of "Theory-of-Everything" is Based on Two Assumptions:

The search for scientific knowledge by humans can come to exhaustion.

- The exhaustion of scientific knowledge has been achieved in the current generation.

The human history testifies exactly the opposite. The search for scientific knowledge never reached exhaustion by any generation. Each time we think we know more about Nature, we realize that there are much more and much deeper things to be learned and understood. If the final "Theory-of-Everything" is found, science would be dead, but science will never die. The Theory-of-Everything (TOE), or ultimate theory, or final theory, which would hopefully unite all the forces and describe all phenomena in the physical world, has long been a dream of astrologists, alchemists and scientists. These thinkers wanted to describe the working of nature, or the working of God, with a single theory of everything. The ancient Chinese alchemists believed that everything in the world were generated from Tai Chi (the Ultimate Origin). Tai Chi generated Yin and Yang (the negative and the positive) that in turn generated the lower level of basic elements (4,5, or 8 fundamental elements), with the Five-Elements Theory most extensively developed.

According to the Five-Elements Theory, everything in the world can be grouped into five categories-metal, wood, water, fire and earth. It was very similar to the western astrological categorization-water, fire, earth and air, with the fifth element ether (quintessence) added on later by Aristotle. The amazing similarity attests that the desire of having a theory of everything is a human nature. Democritus was an early philosopher attempted to unify all phenomena observed in nature. He proposed that the diversity of observed phenomena was due to the motions and collisions of atoms. Archimedes tried to describe "everything" starting from a few axioms. In 17th century, the mechanical philosophy believed that all forces could be ultimately reduced to contact forces between the atoms. Such theory was latter on defeated by Newton's theory of gravitation which was a force between bodies without direct contact [27, 28].

In 1814, Laplace suggested that if the position and velocity of every particle at a given time were known, a powerful intellect could calculate the position of any particle at any other time [29, 30].

An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.

Laplace thus envisaged a combination of gravitation and mechanics as a theory of everything.

2.3. Laplace's Dream Could Not Be Realized for Many Reasons:

- One can predict the future position and velocity of a point particle only in vacuum. The future of a particle is unpredictable if there are dynamic frictions and interactions during the flight.
- It is impossible to specify the initial conditions when one is dealing with a huge number of particles such as a volume of air (6.02×10^{23} per mole).
- Even if the initial conditions are given, the futures of particles are complicated by the frequent collisions. Even there is no collision, the time of calculation required to predict the future is way beyond any human or computer can accomplish.

- If the particles are solidified into a rigid body, the movement of the rigid body in a continuous medium cannot be described by simple equations. It depends on its shape as well. It is impossible to predict at what spot a falling leaf will land.
- The many interactions such as electromagnetic and nuclear interaction, which Laplace either did not know very well or did not know at all, would complicate Laplace's theory and defeat his prediction. For example, it is impossible to predict the future of the individual particles in plasma even in a controlled thermal nuclear fusion. It is quite amazing that a great mind like Laplace would believe in a sort of Theory-of-Everything.

In 1820, Hans Christian Ørsted discovered a connection between electricity and magnetism, followed by James Clerk Maxwell's work on a theory of electromagnetism that culminated in 1865. It gradually became apparent that many forces-contact forces, elasticity, viscosity, friction, and chemical bonding force-resulted from electrical interactions between the smallest particles of matter. By 1890s, some physicists proclaimed that physics was just about complete with nothing left to be done but to carry measurements to a few more decimal places. In a talk at the University of Chicago, Albert Michelson remarked: "It seems probable that most of the grand underlying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all the phenomena which come under our notice…… An eminent physicist has remarked that the future truths of Physical Science are to be looked for in the sixths place of decimals." The "eminent physicist" was believed to be Lord Kelvin who was widely quoted as having said that there was nothing new to be discovered in physics and that all that remained was more and more precise measurement [31].

In 1900, David Hilbert published a famous list of mathematical problems. In Hilbert's sixth problem, he challenged physicists to find an axiomatic basis to all of physics. He actually asked for a theory of everything [32]. After 1915, when Albert Einstein published his theory of general relativity, the search for a unified field theory combining gravity with electromagnetism began with a renewed interest. Einstein then spent thirty years searching for a "unified field theory" of these two forces. His quixotic quest isolated Einstein from the mainstream physicists who were far more excited about the newly emerging framework of quantum mechanics. Einstein ultimately failed to find a unified theory. Nonetheless, his dream of discovering a unified theory had motivated the modern physicists to search for a final Theory-of-Everything along the approach of quantum field theory.

It is interesting to note that many dreamers of Theory-of-Everything are very capable scientists, but not nearly as good philosophers. More than two thousand years ago, Euclid established plane geometry. It is so beautiful, rigorous and systematic that it stands the test of science and technology over more than two thousand years. It is still used by modern human beings in their scientific and engineering practices. Another top scientist of about the same time was Archimedes. Euclid and Archimedes were certainly among the most intelligent scientists in human history, but if they believed that they had found the final theory of everything, or believed in its existence, they would be philosophical dwarfs. Isaac Newton was an intellectual giant in both physics and mathematics, but he would be a philosophical dwarf if he believed that he had found the final theory of everything. He did not even have a good understanding of electromagnetism. James Maxwell was intelligent enough to unify electricity and magnetism, but he would be a philosophical dwarf if he believed that he had found the final theory of everything. He did not have any idea about radioactivity and nuclear force. Any modern giant in science would be philosophically naive if he believes that this generation has found all fundamental laws of Nature.

In spite of the historical lessons, some of the prominent scientists of 20th century still proclaim the final Theory-of-Everything. They believe that no more fundamental forces exist other than the four fundamental forces we know, and that the final theory of everything would be found if we can unify the four fundamental forces. But there are so many things we do not know. We don't even know for sure the nuclear force as a function of distance and velocity. Even the prevailing Standard Model of particle physics fails to present a satisfactory description of the strong interactions. No one knows how to include the gravitational force into a unification theory to his own satisfaction. How can we claim we know everything?

If one opens his eyes to look at the broader scientific landscape, he should see many outstanding fundamental issues that we don't really understand. Do we really know how the life was developed from the inorganic elements? Is the primitive "organic soap" a satisfactory and quantitative description? Do we know why and how the DNAs are passing down the parents' characteristics to their children? Do we know why the molecules are happy when they have eight electrons in the outmost orbit? Why is the helium atom stable with only two electrons? Why would the Fermions obey Pauli Exclusion Principle? Why is uranium235 explosive and uranium238 stable although there binding energies per nucleon are almost equal? The list of unanswered questions goes on and on. There are things that we do not even know their existence and how to formulate questions about it. Before Rontgen and Becquerel discovered X-ray and radioactivity at the end of 19^{th} century, no one would ask about it because people didn't even know the existence of radioactivity. How can we be sure that no similar surprising discoveries would occur in the future? Does it make any scientific and philosophical sense to say that the great discoveries have been exhausted in our generation? The proponents of the "Final Theory-of-Everything" do not seem to understand the greatness and depth of Mother Nature. Our posterities would laugh at our ignorance and presumption like we do our ancestors who did not know even the freshman physics.

In the primitive time when the mankind knew very little about the Mother Nature, almost all extraordinary natural phenomena were ascribed to the behavior of Gods, and that was the time when the various astrological and theological Theories-of-Everything flourished in the different centers of civilization. Whence a theory was established as a religious doctrine, it became a "final" theory that did not allow any challenge or revision. Any slightest change would be condemned as heresy. The notion of "Final Theory-of-Everything" is astrological and theological, not scientific. After the Enlightenment and Renaissance, the human intelligence grew matured enough to establish a real science in modern sense. The more the mankind knows about the nature, the more scientists realize that there won't be the end of scientific search and research. The more we know, the more we realize that there are more we do not know. The pursuit of Theory-Of-Everything is a major mistake in the mission of modern physics.

However, the pursuit of Theory-Of-Everything seems to have become a self-justified mission of physical science. What can be more noble a task than building a Tower of Babel that would allow us to understand God's mind? Such has been used to argue for building the SCC in the United States, and to argue for building a super collider bigger than LHC in China. The huge tax burden is unbearable, but the financial burden is nothing compared to the detrimental consequences of misleading the scientific community with theological pursuit.

3. Conclusion

Equations (1) and (2) show that the gravitational force and the electromagnetic force can be described by exactly the same equation. The only difference here is that in place of electric charge q we now have the mass *m*. The different constants *k* and *G* are simply the indicators of strength of the interacting forces. The two equations (1) and (2) can be expressed in a unified equation:

$$\mathbf{F} = \frac{S}{r^2}\left[\hat{\mathbf{r}} + \frac{1}{c^2}\mathbf{v}'\times\left(\mathbf{v}\times\hat{\mathbf{r}}\right)\right] \qquad (49)$$

Where

$$S = k_1 qq' - Gmm' \qquad (50)$$

is the strength of the interaction. The strength can be dominated either by the gravitational force or by the electromagnetic force, depending on the relative composition of the mass and the charge. What is amazing is that the force law alone is sufficient to derive all the relevant laws governing the electromagnetic and gravitational interactions, including the wave equation. It is a testimony of the consistency of the theory and justification of our generalization of Newton's Law of gravitation. Equations (49) and (50) are the mathematical statement of the unification, reinforced by the fact that the field equations and wave equations are identical.

We can compare our unification with the unification of electroweak theory of the Standard Model. The electroweak theory can deal with the interactions in which the electric and the weak interactions must BOTH present. It fails when there is only one interaction present. It is like an elixir claimed to be able to cure 100 diseases, but it is effective only when all the hundred diseases are present together, and fails if only a single disease is present. Compared to the standard electroweak unification, our unification is by far more effective, rigorous, and simple. It is comparable to the unification of electric and magnetic forces.

The first achievement of our theory is the unification of the two macroscopic forces based on the generalization of Newton's Law of gravitation without any additional ad hoc hypothesis. With the Newton-Wang framework, the theory of gravitation is now complete. The logic and mathematics are rigorous and simple. The beauty and simplicity of the unification are so compelling that leave no doubt as to the reasonableness and correctness of the unification theory. The second achievement of our theory is the revelation of the essence of the inverse-square law that governs both the electrodynamic and the gravitational interactions. We have demonstrated that the inverse square law is the result of the conservation of the total static and dynamic fluxes as expressed in Gauss' law and the newly discovered Wang's law. The Gauss' Law says that the mass is conserved, and Wang's Law says that the total momentum transmitted into space is conserved. The third achievement of our unification theory is a logical and natural solution to the spooky action-at-distance that bothered physicists for over a century. It turns out that the propagation of the gravitational interaction is nothing different from the propagation of electromagnetic wave. With the Newton-Wang framework, there is no more Achilles heal of action-at-distance in the classical theory of gravitation. The fourth achievement of out theory is a rigorous derivation of the gravitational wave equation and its solution. The prediction that the gravitational wave is propagated with speed of light can be used to test our unification theory.

The unification of gravitational and electromagnetic forces opens new windows for further researches into deeper questions: Why would there be different strengths for the two fundamental interactions? Is charge related to mass? If yes, how? Why do same masses attract while same charges repel? Why there are two types of charges but only one type of mass? We venture to predict the positive and fruitful results flowing out of these researches. Theorists need to show more interests in researches along these directions instead of wasting time and resources in the pursuit of Theory-of-Everything and in mathematical acrobatics in higher dimensions. The classical approach of unifying gravitational and electromagnetic forces is of great significance. It has indicated that the idea of unifying gravitational force with other fundamental forces within the framework of general relativity and quantum field theory may not be the right approach.

Wang has given a thorough review of the multitude of fundamental inconsistencies of general relativity [33-37] and the multitude of fundamental problems of the Standard Model of particle physics [38, 39]. These review works give the reasons for the failure of unification along the approaches of general relativity and quantum field theory. If we can explain classically the propagation of gravitational wave and unify gravitational force with electromagnetic force, what is the need of complicating gravitational theory with Riemann geometry? The classical approach of unification poses a direct challenge to the current prevailing mainstream ideology and doctrine: are the classical theories and methodology really obsolete and incorrect? Is the current mainstream theoretical physics really correct and unchallengeable? The achievement seems to be too great to believe, and the significance of it will take some time for the physics community to digest.

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