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This article adopts John Wheeler's idea that on the Planck scale, the quantum vacuum has rapid Planck length vacuum fluctuations he named "quantum foam". With the addition of other assumptions, the quantum vacuum is modeled as a quantum mechanical medium with quantifiable impedance, bulk modulus, and speed of light wave propagation. This medium is proposed to have the properties of a universal field, capable of generating all particles and forces. All other fields are modeled as resonances within this universal field. To test this hypothesis, a model of an electron is created using only this medium. This electron model is a quantized rotating wave with undetectable amplitude of Planck length and $\hbar/2$ angular momentum. Tests of this model approximately generate an electron's energy, rest mass and de Broglie waves. However, this model unexpectantly also creates a standing wave "cloud" that distorts the surrounding universal field. This distortion has quantifiable properties corresponding to an electron's electric and gravitational fields. This wave-based model of an electron's gravitational and electrostatic forces predicts these forces are united through a square exponent. Equations in Section 12 prove this prediction is correct. It is possible to go directly to page 21 to see these surprising equations.

1. Introduction

This article tests the proposal that everything in the universe is derived from a single universal field. A physical structure of this universal field is proposed, and multiple theoretical tests are conducted. The following quote describes the current concept of fields in quantum field theory. "According to contemporary physics, the universe is made up of matter fields, whose quanta are fermions and force fields whose quanta are bosons. All these fields have zero-point energy" [1].

If everything observable in the universe is derived from fields, this means fields (not particles) are the foundation of the universe. The properties of fields are currently designated at points in spacetime as a number or tensor [2-4]. However, the physical substance and underlying structure of fields are currently treated as a mystery. John Wheeler said, "A field, although nearly as ethereal as the ether itself, can be said to have physical reality. It occupies space. It contains energy. Its presence eliminates the true vacuum." [5].

This article starts by addressing the mystery of the structure of fields. The first question is, how many fields are required to create everything observable in the universe? The standard model has 17 named particles. Quantum field theory characterizes each of these particles as excitations of their respective fields [6]. Do we need to model 17 overlapping fields to create everything in the universe? This is a complex and even chaotic foundation for a model of the universe.

A possible insight into the structure of fundamental particles comes from the fact that light, confined in a hypothetical reflecting box, exhibits many particle-like properties. For example, it will be shown that *confined light* has rest mass, relativistic length contraction and similarities to de Broglie waves. An effort was undertaken to generate a model of the universe in which fundamental particles are quantized waves in the zero-point energy (ZPE) of the quantum vacuum. This model would reduce the 17 overlapping fields to 17 resonances in a single universal field.

Quantum mechanical systems continuously fluctuate even in their lowest energy state [1]. This ZPE also applies to the quantum vacuum. The quantum vacuum can be modeled as a sea of harmonic oscillators with energy $E = \hbar\omega/2$, where the maximum angular frequency (ω) in this equation is Planck frequency ($\omega_p \approx 10^{43}$ rad/s). The volume (V) of each harmonic oscillator in space scales with wavelength cubed ($V = k\lambda\!\!\!^{-}{}^3 = kc^3/\omega^3$) where $\lambda\!\!\!^{-} \equiv c/\omega$ is designated angular wavelength and k is a numerical constant near 1. If the fundamental frequency is assumed to be approximately Planck frequency $\omega \approx \omega_p$, then the fundamental wavelength would be Planck length, and the implied

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energy density of vacuum ZPE would be approximately Planck energy density ($c^7/\hbar G^2 \approx 10^{113}$ J/m^3).

General relativity (GR) uses a semi-classical model of the vacuum that does not incorporate ħ, virtual particles, or vacuum fluctuations. The average *observable* energy density of the universe from cosmology and GR is about 10^{-9} J/m^3. Therefore, a vacuum energy density of about 10^{113} J/m^3 is about 10^{122} times larger than the observable energy density of the universe. This enormous difference has been called "the worst theoretical prediction in the history of physics." [7] This mystery is designated the "cosmological constant problem." [8, 9] A comprehensive review article on the cosmological constant problem with over 250 references concludes, "None of the approaches described above is a real outstanding candidate for a solution of the 'old' cosmological constant problem." [10] Almost all these papers attempt to show how the 10^{113} J/m^3 can be ignored or eliminated. The two main objections to enormous vacuum energy have been that it is not observable, and it should cause the gravitational collapse of the universe. These objections will be addressed later.

However, there is also a great deal of support for the quantum vacuum having energy-like content. The Casimir effect is a force between two closely spaced reflecting surfaces caused by the exclusion of relatively long wavelength virtual photons (ZPE). A Google scholar search of the Casimir effect lists more than 1,000 technical articles and a 700-page book [11] on this subject. Besides the static Casimir effect, there are over 150 articles on the dynamic Casimir effect. When two closely spaced surfaces are vibrated, they produce observable physical effects that are different from the static Casimir force between stationary plates. For example, one dynamic Casimir effect experiment observed the creation of photons from the quantum vacuum between vibrating surfaces. This is further supported by these photons also exhibiting two-mode squeezing [12]. Another dynamic Casimir experiment observed phonon heat transfer through the ZPE filled gap between crystalline surfaces. [13] The vast research into the Casimir effect is mentioned because it overwhelmingly establishes experimental proof of vacuum ZPE.

Another type of support for vacuum energy comes from the most accurate theoretical calculation in all of physics. Quantum electrodynamics predicts that the quantum vacuum should have a large density of virtual photons. These fluctuations should shift an electron's magnetic moment by a predictable amount. This effect has been experimentally observed and theoretically calculated. The agreement between theory and experiment is accurate to 10 significant figures [14 - 16]. The Lamb shift [17] is another accurately calculated physical effect requiring ZPE spacetime fluctuations.

Even though this property of the quantum vacuum has mathematical units of energy density, it does not exhibit the properties we would expect for observable energy density. For example, an energy density of 10^{113} J/m^3 in photons would have Planck temperature ($\sim 10^{32}$ K), and this energy density would form a black hole even in the smallest volume – Planck volume ($\sim 10^{-104}$ m^3).

The quantum vacuum does not have a large *observable* energy density. Instead, it has about 10^{113} J/m^3 of energy-like content, which is in the form of vacuum fluctuations with the amplitude of Planck length. They form the quantum vacuum, which is homogeneous and quiet on the macroscopic scale. *If we define observable energy as anything that generates gravity, then the vacuum fluctuations of ZPE are not observable energy.*

However, rather than assuming vacuum ZPE must somehow be canceled, there is another choice. We know that fields physically exist, but the properties of fields are very different compared to the particles they generate. For example, all fundamental fermions generate gravity, but the fields which generate fermions do not generate gravity. *Therefore, a structural model of a field is required to be made of a medium that does not generate gravity. A field is an incomplete component of particles and forces, which only becomes an observable form of energy when an excitation is added. If vacuum fluctuations are the structure of a field, this completely changes the "cosmological constant problem" debate.*

The quantifiable properties of the universal field are developed in this article. Then this model is subjected to numerous tests. One series of tests demonstrates this universal field is plausibly capable of building an electron. This electron model even generates an electron's gravitational and electrostatic forces with surprising results.

2. Historical perspective

In the 19th century, when light was proven to exhibit wave properties, physicists reasoned that there must be a medium for light wave propagation. The ancient idea of an aether was revived and made into a light propagation medium that fills all of space. However, this model incorrectly predicted the aether should propagate classical waves and have an observable frame of reference. The aether was dropped when experiments failed to find a frame of reference for the aether, and light exhibited non-classical particle properties (photons).

However, space ceased being a true vacuum when quantum physics required space to be filled with multiple fields, virtual particles, zero-point energy, etc. In 1955, John A. Wheeler proposed that the uncertainty principle implied the vacuum must have Planck length fluctuations of spacetime. [18] He named this "quantum foam," but today, it is also named "spacetime foam." This idea is expanded in the last chapter of the authoritative book he coauthored titled *Gravitation* [19]. This book says, "No point is more central than this: empty space is not empty. It is the seat of the most violent physics…. The density of field fluctuation energy in the vacuum ~ 10^{94} g/cm^3 (~10^{113} J/m^3) argues that elementary particles represent a percentage-wise almost completely negligible change in the locally violent conditions that characterize the vacuum…" The structure of these fluctuations is described as follows: "The geometry of space is subject to quantum fluctuations in metric coefficients of the order of: $^{\text{Planck length}}\!/_{\text{length extension of the region under study}}$" [19].

These statements by Wheeler and his coauthors can be condensed into the following two assumptions. *1) The quantum vacuum is a sea of Planck length/time vacuum fluctuations, predominantly at Planck frequency. 2) These fluctuations create vacuum zero-point energy.*

The following additional assumptions are introduced in this article. *3) Vacuum fluctuations make the quantum vacuum a stiff elastic medium capable of propagating waves at the speed of light. 4) This medium is the single universal field which generates everything in the universe.* These four assumptions are the base of this article. Tests will be conducted on wave-based particles and forces derived from these assumptions.

3. Names and units

This article makes a distinction between observable energy (fermions, bosons, etc.) and the unobservable Planck length/time vacuum fluctuations of ZPE. Observable energy is defined here as *anything that generates gravity*. The vacuum harmonic oscillations do not meet this definition even though these fluctuations have energy-like properties, including units of energy (kg·m^2/s^2) when expressed mathematically. *Therefore, the name "quasi-energy" will be used to describe the energy-like vacuum fluctuations with units of energy but do not generate gravity.*

A fermion's Compton wavelength is $\lambda_c = h/mc$. A circle that is 1 Compton wavelength in circumference has a Compton radius of $r_c \equiv \lambda_c/2\pi = \hbar/mc$. This radius is used frequently and designated the "Compton radius r_c" or the "Compton angular wavelength" $\lambda\!\!\!^{-}_c = r_c$.

This exploratory article also addresses the big picture of fundamental concepts. Approximations are used by substituting the symbol k for unknown numerical constants near 1. Another simplification is to ignore the vectors of forces and only deal with the magnitude of forces. Electrons are use in examples, but these examples also apply to muons or tauons. Discussions of electric fields also imply magnetic properties.

The word "particle" usually does not need to be defined. However, in this article subatomic "particles", such as an electron, will be modeled as quantized waves that exhibit known wave-particle duality. The term "particle" will still be used to describe this quantized wave model of electrons, muons, etc.

This article also elevates Planck length beyond its usual definition. The symbol l_p is usually used to represent Planck length. However, this article uses the symbol L_p to imply it is also the fundamental wave amplitude in the universal field. Below is a list of base Planck units used in this article.

Planck length:	$L_p = (\hbar G/c^3)^{1/2} = 1.62\times10^{-35}$ m
Planck time:	$T_p = (\hbar G/c^5)^{1/2} = 5.39\times10^{-44}$ s
Planck mass:	$m_p = (\hbar c/G)^{1/2} = 2.18\times10^{-8}$ kg
Planck frequency	$\omega_p = (c^5/\hbar G)^{1/2} = 1.86\times10^{43}$ rad/s
Planck force:	$F_p = c^4/G = 1.21\times10^{44}$ N
Planck density:	$\rho_p = c^5/\hbar G^2 = 5.16\times10^{96}$ kg/m^3
Planck energy:	$E_p = (\hbar c^5/G)^{1/2} = 1.96\times10^9$ J
Planck energy density:	$U_p = c^7/\hbar G^2 = 4.64\times10^{113}$ J/m^3
Planck pressure	$\mathcal{P}_p = c^7/\hbar G^2 = 4.64\times10^{113}$ N/m^2
Planck charge	$Q_p = (4\pi\varepsilon_o\hbar c)^{1/2} = 1.88\times10^{-18}$ C
Planck voltage:	$\mathcal{V}_p = (c^4/4\pi\varepsilon_o G)^{1/2} = 1.04\times10^{27}\ \mathcal{V}$
Planck electric field	$\mathcal{E}_p = (c^7/4\pi\varepsilon_o\hbar G^2)^{1/2} = 6.5\times10^{61}\mathcal{V}$/m
Planck impedance	$Z_p = 1/4\pi\varepsilon_o c = 29.98\ \Omega$

This article introduces many new terms. Here is a list of a few of the symbols that will be commonly used.

$\omega_c = mc^2/\hbar$	Compton angular frequency
$\lambda\!\!\!^{-} = \lambda/2\pi = c/\omega$	Angular wavelength (Lambda bar)
$\lambda\!\!\!^{-}_c = \hbar/mc$	Compton angular wavelength of a fermion
$r_c \equiv \hbar/mc = c/\omega_c$	Compton radius of a fermion
$\mathcal{N} \equiv r/\lambda\!\!\!^{-}_c = rmc/\hbar$	Wave scaling number
$A_r \equiv L_p/r$	Radial strain amplitude
$Z_S \equiv c^3/G$	Strain impedance of spacetime
$Z_D \equiv c\omega^2/G$	Displacement impedance of spacetime
$\alpha = e^2/4\pi\varepsilon_o\hbar c \approx {}^1/_{137}$	Fine structure constant
$e = (\alpha 4\pi\varepsilon_o\hbar c)^{1/2} \approx 1.6\times10^{-19}$ C	Elementary charge e
$F_e = e^2/4\pi\varepsilon_o r^2$	electrostatic force between 2 electrons
$F_{e\alpha} \equiv \alpha^{-1}F_e = \hbar c/r^2$	α adjusted force between 2 electrons

4. Field analysis

4.1 Model of the universal field

The standard model is a field theory with multiple fields filling space. However, the simplest model would be for everything in the universe to be derived from a single field. There is an additional reason to suspect there is only one universal field. The covariance of the laws of physics requires coordination between everything in the universe. For example, special relativity describes effects on length, time, energy, etc., which result in Lorentz covariance. These effects can only be explained if there is coordination between all particles and forces. This appears impossible if particles and forces are excitations of many independent fields. However, this coordination is reasonable if everything, including other fields, is derived from a single universal field. For example, the electron field could be a resonance at 7.76×10^{20} rad/s in the Planck frequency universal field.

The only function of the luminiferous aether was to propagate light. Therefore, measurement devices such as clocks, rulers, and interferometers were assumed to be independent of the aether and should be able to measure the movement of the earth relative to the aether. However, if everything is derived from a single universal field, then it is possible to have covariance of all the laws of physics. Lorentz covariance would occur because rulers, clocks, forces, interferometers etc., all scale to make it impossible to experimentally measure motion relative to a universal field. This would satisfy Einstein's requirement for a "relativistic aether." [20] Evidence for the existence of the single field would be partly hidden because everything in nature is participating in the coverup. Even the laws of physics are evidence of unrecognized vacuum content.

The model of the single universal field must start by giving a quantifiable description of spacetime fluctuations that form vacuum ZPE. We start by describing the model of a single harmonic oscillator in the quantum vacuum. There are no sharp boundaries in this model. An approximately spherical volume of the universal field about Planck length ($L_p \approx 10^{-35}$ m) in radius undergoes both spatial and temporal fluctuations at approximately Planck frequency ($\omega_p \approx 10^{43}$ rad/s). Therefore, even describing the size as approximately Planck length in radius is a problem because the distance between points is fluctuating. Therefore, the size range is an approximate average. Also, the rate of time is being modulated. A comparison of two hypothetical perfect point clocks separated by more than Planck length would show that they speed up and slow down relative to each other. They will differ by ± Planck time (T_p) because of the fluctuating rates of time at each location.

The gravitational distortion of the distance between points was experimentally demonstrated by the Shapiro experiment [21, 22]. This experiment used radar to track the planet Venus as it passed behind the Sun. The Sun's gravity caused a maximum relativistic delay of 190 μs on the half-hour round trip transit time. One interpretation is half the gravitational delay was due to the gravitational slowing of the coordinate speed of light, and half the delay was due to an increase in the radar path length. This implies a gravitational increase in physical volume.

The following thought experiment will help to explain the proposed space/time fluctuations. Imagine a spherical mass with the density of a neutron star. If there is a small, evacuated cavity at the center of this mass, this vacuum volume would not have any gravitational acceleration. However, this internal space would have a slower rate of time and a larger proper distance between stationary points compared to the same space without the surrounding mass (larger volume – slower rate of time).

Next, imagine this cavity volume if a hypothetical negative gravity (antigravity) substance is substituted for the surrounding shell. Surrounding a cavity with this hypothetical negative gravity substance would produce the opposite effects including, 1) a faster rate of time, 2) a smaller proper distance between stationary points (smaller volume), and 3) no gravitational acceleration.

A substance that generates negative gravity must be made of "negative energy." There are no examples of negative energy, but the concept is useful. *The quantum vacuum model to be tested has spatial and temporal fluctuations between positive and negative energy distortions. These average to zero observable energy and zero average distortion. Therefore, the macroscopic average appears to be a quiet vacuum with no observable energy. However, these fluctuations give the quantum vacuum its physical properties such as constants c, G and $\hbar$.* For example, the fluctuations are happening at the speed of light ($L_p\omega_p = c$). Therefore, waves in this medium would propagate at this speed.

In transition, we move from describing a single Planck frequency harmonic oscillator, to describing many of these oscillators forming a 2-dimensional X-Y plane. Figure 1 depicts many of the individual Planck frequency harmonic oscillators previously described.

Each hill and each valley in Fig 1 represent vacuum fluctuations, which average roughly Planck length in radius. A hill represents a volume that has momentarily expanded its radius. For illustration, we assume each hill represents a volume that has a $L_p/2$ expansion of radius, and a valley represents a volume that has a $L_p/2$ contraction of its radius. The fluctuations are at

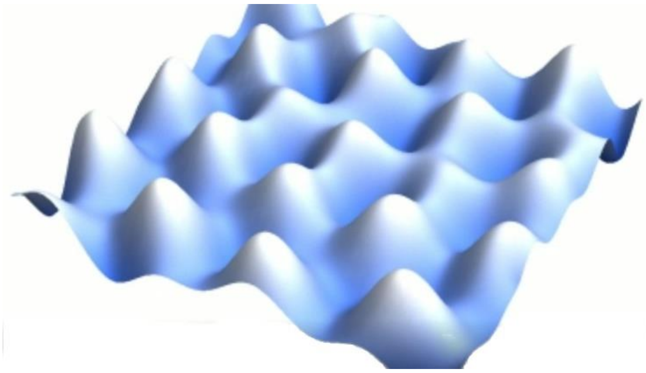

Fig 1. This is an elastic membrane representation of the fluctuating quantum vacuum. The hills represent spatial expansion, and the valleys represent spatial contraction. The displacement amplitude is about Planck length ($\sim 10^{-35}$ m) and the frequency is about Planck frequency ($\sim 10^{43}$ rad/s).

approximately Planck frequency. The complete model is expanded to 3 spatial dimensions.

The last step in this description is to reconcile this with the known characteristics of quantum mechanical harmonic oscillators and ZPE. So far, the description has been of Planck scale volumes oscillating at approximately Planck frequency. Larger spherical volumes with radius *r,* contain vast numbers of these L_p harmonic oscillators. Collectively, they also produce a "noise" that is a distributed L_p fluctuation across radius *r* at the lower frequency of $\omega = c/r$. These larger volumes also achieve the quasi-energy of $E = \hbar\omega/2$ of ZPE oscillators. As discussed later, a few frequencies are resonances. These resonances are preferred and associated with virtual particle creation.

This model is supported by the fact that the distance between two points cannot be measured to the accuracy of L_p, and a time interval cannot be measured to the accuracy of T_p. [23 - 26]. These limits are proposed to be the result of the vacuum "noise" associated with the L_p and T_p vacuum fluctuations over macroscopic distances limiting the accuracy of measurements.

4.2 Gravitational collapse avoided

This model of the quantum vacuum has a quasi-energy density of about $U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3 and the universal field pressure of $\mathcal{P}_p = c^7/\hbar G^2 \approx 10^{113}$ N/m^2. This is not 10^{113} J/m^3 of energy possessing spin, such as 10^{113} J/m^3 of leptons, quarks, and bosons. These fluctuations do not possess spin. Should this quasi-energy generate gravity and gravitationally collapse? Four answers are presented that give different explanations for no gravitational collapse.

First, in the article "Hiding the cosmological constant" [27], Steven Carlip does a mathematical analysis of the vacuum consisting of Planck length and Planck time "spacetime fluctuations." Using GR, he models the spacetime fluctuations as producing both expansion and contraction on the scale of Planck length. He concludes that these fluctuations can offset. He states, "high curvature at small scales average to zero macroscopically."

Second, fermions and bosons are currently considered to be excitations of their respective fields. We are introducing the concept of a single universal field. However, the fact remains, there is a fundamental difference between the "excitations" (fermions, bosons) and the field itself. Equations and concepts developed to describe the gravitational effects of fermions and bosons (excitations) should not be assumed to apply the field itself. In fact, it is a *requirement* that a pristine field must have different properties than a field containing an excitation. The addition of an excitation converts a portion of a pristine field into a fermion or boson. The excitation will be discussed later.

Third, the L_p and T_p oscillating distortions in the universal field are equivalent to an oscillation between a gravity-like distortion (large volume – slow rate of time) and negative gravity distortion (small volume – fast rate of time). This would require an oscillation between positive and negative energy distortions. On the macroscopic scale, the positive and negative energy distortions cancel. Therefore, there is no macroscopic rate of time gradient in pristine space, which means there is no gravitational acceleration attempting to collapse the universe.

Fourth, even if we assume a tendency for gravitational collapse, this would be prevented by the Planck pressure component ($\mathcal{P}_p$) of the universal field model. It is not possible to compress this universal field to a pressure greater than Planck pressure or compress waves to a wavelength shorter than Planck length. Therefore, the model itself prevents further compression. There are no singularities with infinite energy density in this quantized wave model.

Fields do not exert gravity. These four explanations describe how this model of a universal field meets the requirement of having quasi-energy but not producing gravity.

4.3 Quantifying the universal field

The model of the universal field needs to be converted to equations, which can then be tested. The conversion starts with the well-known spectral energy density of ZPE, which is $U_o(\omega) = \hbar\omega^3/2\pi^2c^3$ [1].

$$U_Z = \int_{\omega_1}^{\omega_2} \frac{\hbar\omega^3}{2\pi^2 c^3} d\omega = \frac{1}{8\pi^2}\frac{\hbar}{c^3}\left(\omega_2^4 - \omega_1^4\right) \Rightarrow k\frac{\hbar\omega^4}{c^3} \quad (1)$$

Equation (1) integrates this spectral energy density to obtain the energy density between two frequencies: a lower frequency ω_1 and a higher frequency ω_2. Equation (1) carries this one step further (designated by arrow ⇒) and assumes we want all frequencies equal to or less than ω_2. Therefore, $\omega_1 = 0$, and ω_2 is merely designated ω. Also, the numerical constant $1/8\pi^2$ has been replaced with k to broaden the usefulness of this equation, as discussed later.

Next, we want to test whether this sea of Planck length/time vacuum fluctuations, predominantly at Planck frequency, can be treated as a quantum mechanical acoustic medium. A quantum mechanical wave with acoustic properties should slightly distort the sea of Planck frequency harmonic oscillators. Individual oscillators should slightly increase and decrease their frequency as a wave passes. This causes the universal field to be able to absorb and return energy to the propagating wave. The ability to store and return energy to a wave means the universal field should exhibit elasticity (bulk modulus) and acoustic impedance. We want to understand and quantify these acoustic properties of the universal field.

John Wheeler's characterization of the quantum vacuum was converted to the following two assumptions: 1) *The quantum vacuum is a sea of Planck length/time vacuum fluctuations, predominantly at Planck frequency*. 2) *These fluctuations create vacuum zero-point energy*. Even though Planck frequency is predominant, combinations of many harmonic oscillators are assumed to create lower frequency beats, which also have amplitude of Planck length (Wheeler's quantum foam). Therefore, the quasi-energy density characteristics of Eq. (1) are assumed to be created by Planck length vacuum fluctuations. The first step in quantifying this medium is to calculate its impedance.

The following universal equation is used for this analysis $I = kA^2\omega^2 Z$. In this, (I) is the intensity of a wave with amplitude (A) in medium with (Z) impedance, and (k) is a numerical constant. This equation can be converted to energy density (U) by dividing intensity by the speed of propagation, which for waves in this medium is c yielding: $U = I/c$. This results in Eq. (2).

$$U = \frac{k}{c} A^2\omega^2 Z \quad \mathrm{J/m^3} \qquad (2)$$

$$k\frac{\hbar\omega^4}{c^3} = \frac{k}{c}\left(\frac{\hbar G}{c^3}\right)\omega^2 Z \qquad (3)$$

$$Z = Z_D \equiv \frac{c\omega^2}{G} \quad \mathrm{kg/m^2s} \qquad (4)$$

We can solve for the impedance of spacetime created by Planck length vacuum fluctuations (noise) if we equate Eq. (1) to Eq. (2), ignore numerical constants k, and set amplitude A equal to Planck length $A = L_p = (\hbar G/c^3)^{1/2}$. Then we solve for Z. This is done in Eq. (3), yielding Eq. (4). *The calculated "displacement impedance of spacetime" is $Z_D \equiv c\omega^2/G$. This impedance is the key to quantifying the universal field. Most of the equations, proofs, and predictions to follow were derived from this impedance.*

We can quickly perform a test of this impedance to see if it is compatible with the universal field model. We will solve for the quasi-energy density of the universal field by assuming Planck frequency fluctuations. Therefore, substitute ($\omega = \omega_p$), ($A = L_p$), ($k = 1$), and $Z = Z_D$ into Eq. (2). When these substitutions are made, we obtain that the quasi-energy density equals Planck energy density ($U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3). This is the correct answer required for this impedance to be compatible with the universal field model.

We also need to generate the impedance of spacetime in a form with different units. The displacement impedance $Z_D \equiv c\omega^2/G$ has units of kg/m^{2}s which is compatible with amplitude expressed with units of length. However, often it is more convenient to express the amplitude of a sine wave as a dimensionless number representing the maximum strain – the sine wave's maximum slope. This dimensionless strain amplitude is obtained by dividing the displacement amplitude $A = L_p = (\hbar G/c^3)^{1/2}$ by a wave's angular wavelength $\lambda\!\!\!^{-} = \lambda/2\pi$. This creates dimensionless amplitude $A = L_p/\lambda\!\!\!^{-} = \omega(\hbar G/c^5)^{1/2}$. When this substitution is made in Eq. (3), we replace $(\hbar G/c^3)$ with $(\omega^2\hbar G/c^5)$.

$$Z_S \equiv \frac{c^3}{G} \approx 4.04\times 10^{35} \ \mathrm{kg/s} \qquad (5)$$

These changes convert the displacement impedance Z_D in Eq. (4) into the "strain impedance of spacetime" $Z_S = c^3/G$ in Eq. (5) with units of kg/s. This is the same fundamental impedance, but it has units compatible with dimensionless strain amplitude.

In summary, the quantum vacuum is modeled as a sea of Planck length and Planck time vacuum fluctuations, predominantly at Planck frequency. This creates a medium with similarities to an acoustic medium. It propagates waves at the speed of light, but the displacement impedance of this medium is frequency dependent ($Z_D \equiv c\omega^2/G$). This medium will be shown to be ideally suited to generate the wave-particle properties of fundamental particles.

4.4 Impedance calculation from GWs

Equations (4, 5) are predictions derived from the first three starting assumptions. Is there any proof spacetime actually exhibits this predicted impedance? We can test this concept because gravitational waves (GWs) propagate in spacetime and should encounter this impedance, if it exists.

Surprising support indeed does come from GWs. In the 1991 book titled *Detection of gravitational waves* [28], the authors wrote, "Starting from Einstein's field equation … the coupling constant $c^4/8\pi G$ can be considered a metrical stiffness (see Sakharov 1968 [29]) … By analogy with acoustic waves, we can identify the quantity c^3/G with the characteristic impedance of the medium. … The problem of detecting gravitational wave radiation can be understood as an impedance-matching problem." This same point is made in the more recent (2012) book on GW detectors [30]. Neither of these books show how the "analogy with acoustic waves" generates the implied impedance c^3/G. However, both books [28, 30] give the equation for the intensity of a GW in the limit of a weak plane wave. This equation is shown below as Eq. (6) in a slightly modified format.

$$I = \left(\frac{1}{16\pi}\right)\left(\frac{\Delta L}{L}\right)^2 \omega^2 \left(\frac{c^3}{G}\right) \ \text{kg/s}^3 \qquad (6)$$

Equation (6) has arranged the terms in the GW intensity equation to permit an easy comparison to the universal intensity equation $I = kA^2\omega^2Z$. Making this comparison, it is evident that $k = 1/16\pi$ and amplitude is $A = \Delta L/L$. *Most important, the strain impedance encountered by GWs is $Z_S \equiv c^3/G$. This is the same strain impedance, as previously calculated in Eq. (5). Therefore, if GWs are treated as waves propagating in an acoustic medium, the impedance encountered by GWs matches the impedance predicted by assuming vacuum ZPE has Planck length fluctuation amplitude. This same impedance will later be shown to also be encountered by electromagnetic (EM) radiation.*

In Eq. (6), $\Delta L/L$ is the GWs strain amplitude (maximum slope). When interferometers are used to detect GWs, ΔL is interpreted as the measured fringe shift in an interferometer, and L is the round-trip path length of the interferometer. If we assume the interferometer's round-trip path length, L, is less than about 10% of the GW wavelength, then the maximum strain (maximum slope of the sinusoidal GW) is approximated by $h \approx \Delta L/L$ where $h^2 = h_+^2 + h_\times^2$. The subscripts + and × represent GW polarizations. However, $h \approx \Delta L/L$ is an approximation that becomes completely invalid as the round-trip distance (L) approaches the GW wavelength. The exact strain amplitude (maximum slope) is $\delta/\lambda\!\!\!^-$ where δ is the magnitude of the maximum displacement (with units of length) produced by the sinusoidal GW over an entire wavelength, and lambda bar $\lambda\!\!\!^-$ is angular wavelength ($\lambda\!\!\!^- \equiv \lambda/2\pi$) of the GW. When the strain amplitude approximation $\Delta L/L$ is replaced with the exact strain amplitude $\delta/\lambda\!\!\!^-$, then it is possible to restate Eq. (6) in a form where the amplitude is δ.

$$I = \left(\frac{1}{16\pi}\right)\delta^2\omega^2\left(\frac{c^3}{G\lambda\!\!\!^{-2}}\right) \ \text{kg/s}^3 \qquad (7)$$

$$Z_D \equiv \frac{c^3}{G\lambda\!\!\!^{-2}} = \frac{c\omega^2}{G} \ \text{kg/m}^2\text{s} \qquad (8)$$

Equation (7) expresses amplitude $A = \delta$ (displacement amplitude) with dimensions of length. This change transfers the angular wavelength $\lambda\!\!\!^-$ to become part of the impedance. Equation (8) extracts "displacement impedance Z_D" obtained from Eq. (7). This is the same impedance as Eq. (4), which assumed ZPE had Planck length displacement amplitude. Therefore, GWs encounter the predicted impedance of the universal field.

In acoustics, the wave amplitude is usually defined as the maximum particle displacement δ from the center position. A GW does not physically displace the center of mass of an isolated object, such as an interferometer mirror suspended by wires. Instead, the space between the mirrors is affected such that the distance between mirrors as measured by a laser beam can change without physically displacing the center of mass of the mirrors. Hereafter, the term "displacement amplitude" of a wave in the universal field implies a distortion of the properties of space, which affects the distance between points. This is different from the physical displacement of an object.

4.5 Quasi-density of the universal field

Next, we will calculate the implied density of the universal field using GWs and the analogy of wave propagation in an acoustic medium. The following analysis will imply GWs encounter a property of spacetime that has units of density but does not meet the commonly accepted definition of density having rest mass or generating gravity. Therefore, the term "quasi-density" indicates this is a quantum mechanical property of spacetime with units of density. This density-like property (designated ρ_q) is only revealed to waves that distort the proposed harmonic oscillators (L_p fluctuations) that are the structure of the universal field.

$$\rho_q = k\frac{\omega^2}{G} = k\left(\frac{\omega}{\omega_p}\right)^2 \rho_p = k\left(\frac{L_p}{\lambda\!\!\!^-}\right)^2 \rho_p \ \ \text{kg/m}^3 \qquad (9)$$

$$U_q = k\frac{c^2\omega^2}{G} = k\left(\frac{\omega}{\omega_p}\right)^2 U_p \ \ \text{kg/s}^2\text{m} \qquad (10)$$

The specific impedance of an acoustic medium is defined as $\mathcal{Z} \equiv \rho c_a$ with units of kg/m^2 s. In this, ρ is the density of the acoustic medium, and c_a is the acoustic speed of propagation. For GWs, $c_a = c$. Therefore, we can equate $\mathcal{Z} = Z_D = \rho_q c = c\omega^2/G$ and solve for the universal field quasi-density ρ_q encountered by GWs. The answer is Eq. (9) and Eq. (10) converts this to quasi-energy density U_q. GWs have the numerical constant $k = 1/16\pi$, but the symbol k is used to broaden these equations because other waves in space have different numerical constants. The term "quasi-energy E_q" will also be used.

If we set $\omega = \omega_p$, (Planck frequency) in Eq. (10), then the indicated quasi-energy density of the universal field is: $U_q = kU_p = k\, 4.6 \times 10^{113}$ J/m^3. However, Eq. (10) says waves with a lower frequency than Planck frequency encounter lower quasi-energy density because of the $(\omega/\omega_p)^2$ term. This is because lower frequency waves experience impedance mismatch and only partially couple to $U_p = c^7/\hbar G \approx 10^{113}$ J/m^3.

The quasi-energy density (U_q) of the universal field encountered by wavelength $\lambda\!\!\!^-$ is $U_q = kc^4/G\lambda\!\!\!^-{}^2$. This limiting property of spacetime has a connection to the energy density of black holes. For example, the energy density of a black hole is $U_{bh} = kc^4/Gr_s^2$, where r_s is the black hole's Schwarzschild radius ($r_s = 2Gm/c^2$). *Therefore, the quasi-energy density of the universal field encountered by wavelength $\lambda\!\!\!^-$ is approximately the same as the energy density of a black hole with radius $r_s = \lambda\!\!\!^-$.*

$$U_z = k\frac{\hbar\omega^4}{c^3} = k\left(\frac{\omega}{\omega_p}\right)^4 U_p \ \ \text{kg/s}^2\text{m} \qquad (11)$$

However, one puzzle remains. Equation (1) calculated the ZPE density by integrating the ZPE spectral energy density and obtained $U_z = k\hbar\omega^4/c^3$. This equation is expanded in Eq. (11) to match the form of Eq. (10). Equations (10 and 11) are two different equations for quasi-energy density. The following example illustrates the difference. If $\omega = 1250$ rad/s (~200 Hz), then U_q from Eq. (10) is about 10^{80} times larger than U_z from Eq. (11). The question is: Why should the quasi-energy density of ZPE (U_z) shown in Eq. (11) be much smaller than U_ω shown in Eq. (10)?

The answer is that Eq. (11) calculated the quasi-energy density of ZPE frequencies equal to or less than ω while Eq. (10) calculated the quasi-energy density at all frequencies encountered by a wave in space with frequency ω. A wave in space such as a GW with frequency ω interacts with both higher and lower ZPE frequencies. Even though there is a frequency mismatch term, the frequencies higher than ω dominate because the quasi-energy density increases with ω^4. In the limit of Planck frequency ($\omega = \omega_p$), both Eq. (10 and 11) give the same answer, which is: $U_q = U_z = kc^7/\hbar G^2$. This is because no frequency higher than Planck frequency is possible.

In a fluid, the bulk modulus ($\mathcal{K}$) and the density (ρ) are related by the Newton-Laplace equation $\mathcal{K} = c_a^2\rho$, where c_a is the acoustic speed of sound. Setting $c_a = c$ and $\rho = \rho_q$, *the bulk modulus of the universal field is $\mathcal{K} = U_q = c^2\omega^2/G$.* In an ideal medium, the bulk modulus equals the energy density. Bulk modulus is defined as the ratio of pressure increase to the resultant decrease in volume. The bulk modulus of the universal field (of spacetime) scales with frequency squared ω^2.

4.6 Numerical examples using GW150914

The implications of Eqs. (9 and 10) can be illustrated using the observed characteristics of the GW designated GW150914 [31, 32]. This was the first GW detected by LIGO in September 2015. This GW was a chirp that went from about 30 Hz to 250 Hz. We will analyze the highest amplitude portion of this wave, which is: $\omega \approx 1250$ rad/s (~200 Hz), $\lambda\!\!\!^- = 2.4 \times 10^5$ m, propagation speed c, and strain amplitude $\hbar\!\!\!/ = 1.25 \times 10^{-21}$. From these values, the maximum intensity ($I = 0.02$ w/m^2) and maximum "displacement amplitude" ($\delta = \hbar\!\!\!/\lambda\!\!\!^- \approx 3 \times 10^{-16}$ m.) were calculated using Eq. (6).

There are two ways of calculating the universal field quasi-density ρ_q encountered by this GW at 200 Hz. One way is to make the appropriate substitutions for I, ω and δ into the acoustic equation $\rho = I/\omega^2\delta^2 c$. The other way is to use Eq. (9) setting $k = 1/16\pi$ and $\omega = 1250$ rad/s. Both give the same answer, which is $\rho_q = 4.7 \times 10^{14}$ kg/m^3 for a GW at 200 Hz. This is about 250,000 times the density of a white dwarf star. This universal field quasi-density of the vacuum encountered by GWs converts to quasi-energy density of $U_{gw} = 4\text{x}10^{31}$ J/m^3. This is the quasi-energy density that would be required to propagate a 200 Hz GW at the speed of light with intensity of 0.02 w/m^2 and strain amplitude of only $\Delta L/L \approx 1.25\text{x}10^{-21}$.

Stated another way, the GW is causing an oscillating distortion of the universal field. The ZPE harmonic oscillations of the vacuum are responding by elastically resisting this oscillating distortion by exhibiting impedance, which scales with ω^2. For comparison, an electrical inductor also has impedance, which scales with frequency, but the inductor's impedance scales with ω rather than ω^2. Static spacetime ($\omega = 0$) exhibits no displacement impedance.

So far, we have analyzed GW150914 from the data obtained at the earth's distance of about 1.3 billion light-years. At this distance, the GWs had an intensity of about 0.02 w/m^2. It is informative to also look at a much closer distance of ½ wavelength ($7.5\text{x}10^5$ m). from the merging black holes. The reported peak power of GW150914 was $3.6\text{x}10^{49}$ w [31]. This power achieves an intensity of about $I \approx 5 \text{ x } 10^{36}$ w/m^2 at this relatively close distance. The displacement amplitude required to achieve this intensity at 200 Hz is $\delta \approx 4.8$ km or about 2% of the angular wavelength $\lambda\!\!\!^{-}$ of the GW. At speed of light propagation, this intensity converts to the GW having an energy density of $U = I/c = 1.7\text{x}10^{28}$ J/m^3. This GW at this distance had about 100 times the energy density of a white dwarf star! Even this tremendous energy density is easy for the Planck length vacuum fluctuations of ZPE to propagate. At 200 Hz, the quasi-energy density of the propagation medium available to GWs is about $U_{gw} = 4\text{x}10^{31}$ J/m^3 or $\rho_q = 4.7\text{x}10^{14}$ kg/m^3. Therefore, at 200 Hz, the propagation medium has about 2400 times higher quasi-energy density than the energy density of this GW and can easily propagate a GW with $I \approx 5\text{x}10^{36}$ w/m^2.

4.7 Summary of the universal field

To summarize, the calculated properties of the universal field relating to wave propagation are:

Propagation speed:	$L_p\omega_p = c$
Fundamental amplitude:	$L_p = (\hbar G/c^3)^{1/2} \approx 10^{-35}$ m
Displacement impedance:	$Z_D = c\omega^2/G$
Strain impedance:	$Z_S = c^3/G$
Bulk modulus:	$\mathcal{K} = c^2\omega^2/G$
Quasi-density:	$\rho_q = \omega^2/G$

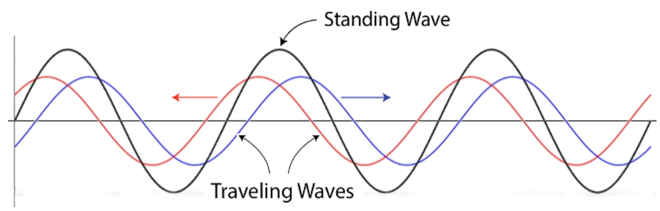

Fig 2. Traveling sine waves propagating in opposite directions create this standing wave when viewed in a stationary frame of reference.

The universal field and excitations of this field are modeled as the only component of the universe. The multiple fields of the standard model are modeled as multiple lower frequency resonances within the approximately Planck frequency universal field.

The simplicity of such a model of the universe makes it possible to quantify and test. This article tests and demonstrates the plausibility of the proposed universal field forming fermions and forces by showing it is possible to develop a quantized wave model of an electron. This model is tested to see if it approximately exhibits an electron's: 1) energy, 2) inertia, 3) de Broglie waves, and 4) point particle properties. Then we will attempt to derive simplified forms of an electron's; 1) gravity, 2) electrical charge, and 3) electromagnetic force.

5. de Broglie wave model

Richard Feynman famously said that "The double-slit experiment has in it the heart of quantum mechanics. In reality, it contains the only mystery." He was talking about the effects of a double slit on both photons and electrons. When electrons pass through a double slit, they exhibit wave properties originally predicted by Louis de Broglie in 1924. Therefore, a key requirement of an electron model is that it must explain these wave-like properties. The effort to model the structure of an electron is helped by the remarkable similarity between the properties of light confined in a 100% reflecting optical resonator and the de Broglie wave properties of an electron. The similarity allows us to determine the frequency and structure required to achieve an electron's de Broglie waves. *Photons are usually visualized as freely propagating. However, photons exhibit particle-like characteristics when reflectors confine them to a specific frame of reference.* This analysis initially assumes laser light reflecting between two 100% reflecting mirrors to form a perfect optical resonator.

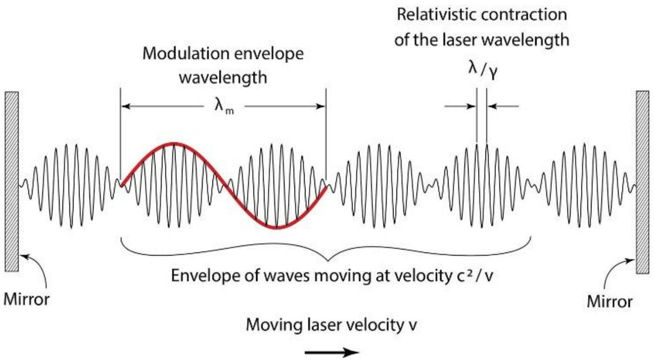

Fig 3. The standing waves in a laser exhibit this modulation envelope when the laser is translated at 5% the speed of light. A short video demonstrating these wave properties is available at: www.quantizedwave.com/video-1

The black standing wave in Fig 2 is formed by the superposition of the two counter-propagating traveling waves (blue and red waves). This confined light has a specific wavelength λ_o, frequency $\omega_{o,}$ and energy E_o.

$$\psi = e^{i\left(k_0 x - \omega_0 t\right)} + e^{i\left(-k_0 x - \omega_0 t\right)} = 2\cos\left(k_0 x\right) e^{-i\omega_0 t} \quad (12)$$

Equation (12) is the superposition of left and right moving plane waves (red and blue waves). In this equation, k_0 is wave number ($k_0 = \omega_0/c = 1/\lambda\!\!\!^{-}_0$). This difference in Doppler shifted waves produces the modulation envelope on the standing waves in Fig 3. The light propagating in the direction of relative motion (moving right) appears to be Doppler shifted up in frequency (ω_R), and light propagating left (ω_L) appears to be Doppler shifted down in frequency.

The relativistic Doppler shifts are $\omega_R = \gamma(1 + \beta)\omega_0$ and $\omega_L = \gamma(1 - \beta)\omega_0$. These Doppler shifts incorporate $\beta = v/c$, and $\gamma = (1 - \beta^2)^{-1/2}$. The following derivation also incorporates the following defined terms.

$$k_R \equiv \omega_R/c = 1/\lambda\!\!\!^{-}_R$$
$$k_L \equiv -\omega_L/c = -1/\lambda\!\!\!^{-}_L$$
$$\omega_+ \equiv \tfrac{1}{2}\left(\omega_R + \omega_L\right) = \gamma\omega_o$$
$$\omega_\times \equiv \tfrac{1}{2}\left(\omega_R - \omega_L\right) = \gamma\beta\omega_o$$
$$k_+ \equiv \tfrac{1}{2}\left(k_R + k_L\right) = \tfrac{1}{2c}\left(\omega_R - \omega_L\right) = \omega_\times/c = \gamma\beta\omega_0/c$$
$$k_\times \equiv \tfrac{1}{2}\left(k_R - k_L\right) = \tfrac{1}{2c}\left(\omega_R + \omega_L\right) = \omega_+/c = \gamma\omega_0/c = \gamma/\lambda\!\!\!^{-}_0$$

Now we can write the wave equation equivalent to Eq. (12) except for a moving frame of reference with relativistic doppler shifted frequencies (ω_R, ω_L) and relativistic wave numbers (k_R, k_L).

$$\begin{aligned}\psi &= e^{i\left(k_L x - \omega_L t\right)} + e^{i\left(k_R x - \omega_R t\right)} \quad (13)\\ &= e^{i\left(\left(k_+ - k_\times\right)x - \left(\omega_+ - \omega_\times\right)t\right)} + e^{i\left(\left(k_+ + k_\times\right)x - \left(\omega_+ + \omega_\times\right)t\right)}\\ &= \left(e^{-i\left(k_\times x - \omega_\times t\right)} + e^{i\left(k_\times x - \omega_\times t\right)}\right)e^{i\left(k_+ x - \omega_+ t\right)}\end{aligned}$$

$$\psi = 2\cos\left(k_\times x - \omega_\times t\right)e^{i\left(k_+ x - \omega_+ t\right)} \quad (14)$$

Equation (13) is the combination of the left moving wave terms (k_L, ω_L) and the right moving wave terms (k_R, ω_R). Equation (14) is equal to Eq. (13), except Eq. (14) has introduced new terms that allow us to quantify previously hidden properties of standing waves viewed in a moving frame of reference. For example, the imaginary part of Eq. (14) $e^{i}(k_+x - \omega_+t)$ generates high-frequency oscillations. These were previously the black standing waves in Fig 2 with wavelength λ_0.

From the imaginary part of Eq. (14), we obtain the following equations for the high-frequency waves ($\omega_+ = \gamma\omega_0$) in Fig 3.

$$v_{group} = v_\times = \frac{\omega_\times}{k_\times} = \frac{\omega_\times}{\omega_+/c} = \beta c = v \quad (15)$$

$$\lambda_\times = \frac{2\pi}{k_\times} = \frac{2\pi c}{\gamma\omega_o} = \frac{\lambda_o}{\gamma} \quad (16)$$

Equation (15) says these high frequency standing waves move with velocity v. This matches the velocity of the resonator. Equation (16) $\lambda_\times = \lambda_o/\gamma$ says that these former standing waves undergo a $1/\gamma$ relativistic length "contraction" compared to the stationary frame wavelength λ_0. Therefore, the same number of standing wavelengths fit between the relativistically contracted resonation mirrors.

Next, we look at the (ω_+) wave properties of the modulation envelope expressed by the ($2\cos\,(k_\times x - \omega_\times t)$) portion of Eq. (14).

$$v_{phase} = v_+ = \frac{\omega_+}{\omega_\times/c} = \frac{c}{\beta} = \frac{c^2}{v} \quad (17)$$

$$\lambda_m = \lambda_+ = \frac{2\pi c}{\gamma\beta\omega_o} = \frac{\lambda_o}{\gamma\beta} \quad (18)$$

Equation (17) ($v_{phase} = c^2/v$) says that this interference effect propagates at a velocity faster than the

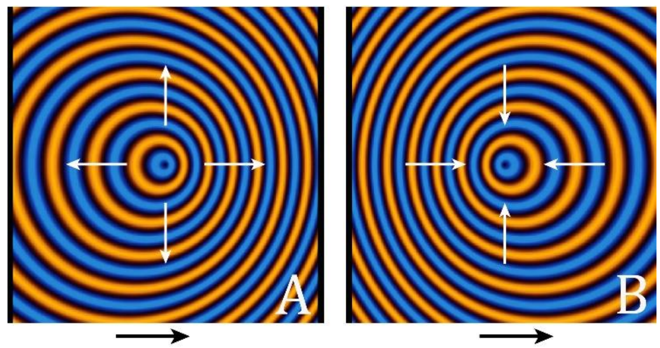

Fig 4. Doppler distorted spherical traveling waves: In Fig 4A**,** the waves are propagating outward from a central source that is moving right at 25% the speed of light. In Fig 4B the waves are propagating inward towards a central point that is moving right at 25% the speed of light.

speed of light. This is the same velocity relationship between the velocity of an electron and the velocity of an electron's de Broglie waves. Equation (18) ($\lambda_m = \lambda_0/\gamma\beta$) says that in the rest frame (v = 0), λ_m is infinitely long (no modulation envelope) but the modulation envelope wavelength gets shorter with increasing velocity. What wavelength equivalent to λ_o in Eqs. (16, 18) is required to achieve an electron's de Broglie wavelength?

$$\lambda_m = \frac{\lambda_0}{\gamma\beta} = \frac{h}{m_e c}\frac{c}{\gamma v} = \frac{h}{\gamma m_e v} = \frac{h}{p} = \lambda_d \qquad (19)$$

Equation (19) shows that setting λ_0 equal to an electron's Compton wavelength ($\lambda_0 = \lambda_c = h/m_e c$) achieves an electron's relativistic de Broglie wavelength $\lambda_d = h/p = h/\gamma m_e v$. This is a key insight. If we want a quantized wave model that generates an electron's de Broglie wavelength and phase velocity, we must incorporate standing waves with a wavelength equal to an electron's Compton wavelength. We are standardizing on angular frequency. Therefore, the angular frequency is $\omega_c = m_e c^2/\hbar = 7.76\times10^{20}$ rad/s and angular wavelength is $\lambda\!\!\!^{-}_c = \hbar/m_e c = 3.86\times10^{-13}$ m.

Equation (16) shows that confined light exhibits relativistic length "contraction" when viewed from a different frame of reference. Also, the standing waves in a moving frame of reference of Fig 3 undergo a relativistic increase in both frequency and energy. For example, the standing waves in the moving frame have frequency given by $v_{phase}/\lambda_m = \gamma\nu_o$ where ν_o is the rest frequency. This is the same as $\omega_\times = \gamma\omega_o$. The relativistic energy E_{rel} of confined light is $E_{rel} = \gamma E_o$. Confined light has a specific frame of reference and exhibits particle-like properties, with special relativity characteristics.

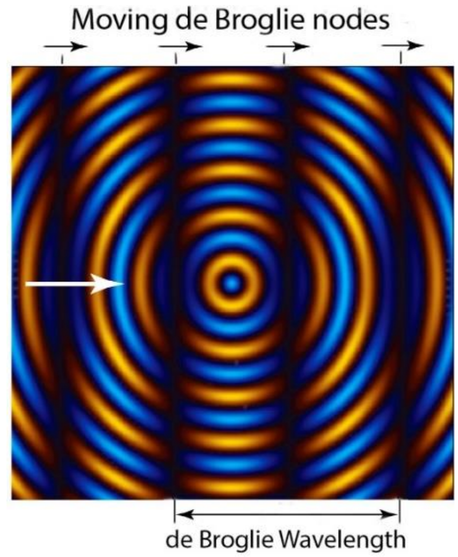

Fig 5. An electron's de Broglie waves are simulated by combining the Doppler distorted waves in Fig. 4A and 4B. This superposition forms these modulation envelope waves. The dark bands are wave nodes. If the waves in Fig 4A and 4B have a wavelength equal to an electron's Compton wavelength, then the modulation envelope in Fig 5 would have the wavelength and propagation speed of an electron's de Broglie waves.

Previously we discussed standing waves formed by counter-propagating plane waves. Now in Fig 4A and 4B we examine the properties of counter-propagating spherical waves. Figure 4A and 4B depict a monopole source of outgoing and incoming spherical waves as explained in the caption. The superposition of Figs 4A and 4B, produces a rapidly moving planar interference pattern shown in Fig 5. This depicts a frozen instant in time. For example, if v = 0.25c, then $v_{phase} = c^2/v = 4c$. Therefore, in this example, the dark bands in Fig 5 are interference effects moving to the right at 4 times the speed of light. These dark bands correspond to the modulation envelope minimums (nodes). Interference effects can move faster than the speed of light. There is a 180-degree phase shift at each node. If the waves in Fig 4A and 4B have a wavelength equal to an electron's Compton wavelength, then the interference effects in Fig 5 would have the wavelength and propagation speed of an electron's de Broglie waves.

The reason for this discussion about standing spherical waves viewed in a moving frame of reference is that this sets limits on the possible quantized wave model of an electron. Equations (15 – 19) showed that standing waves with a wavelength equal to an electron's Compton wavelength create a modulation envelope with the characteristics of an electron's de Broglie waves. The missing piece was whether omni-directional spherical standing waves exhibit the same properties as plane wave standing waves. Figure 5 confirms this. The conclusion is that the electron model must incorporate spherical standing waves oscillating at the electron's Compton frequency ($\sim 10^{20}$ Hz).

6. Inertia simulation

We are almost ready to propose a quantized wave model of an electron, but first, we need to discuss the inertia of confined waves. The last of Einstein's 4 papers in 1905 derived $E = mc^2$ and concluded, "The mass of a body is a measure of its energy content." [33]. In this statement, "mass" is equivalent to "inertia." Light, confined in a reflecting box, exhibits the same inertia as the inertia of a mass with equal energy. The Higgs field does not give inertia to confined light. A review article [34] analyzes seven photon-in-a-box derivations of the inertia of a confined photon.

The inertia of confined light is demonstrated by an example. Laser light reflecting between two 100% reflecting mirrors is confined light. If this optical resonator is stationary, there is equal photon pressure (offsetting forces) on each mirror. However, suppose the resonator is accelerated in a direction aligned with its axis. In the time it takes for light to propagate between the mirrors, the acceleration causes a change in velocity. Light striking the rear reflector is Doppler shifted up in frequency and the light striking the front reflector is Doppler shifted down in frequency. There is more pressure on the rear reflector than the front reflector. This generates a net force resisting acceleration. This net force exactly equals the relativistically correct inertial "force" for an equal energy mass.

A photon propagating freely at the speed of light does not have rest mass. However, a photon confined by reflectors in an optical resonator has the particle-like property of a specific frame of reference. This confined photon also acquires other properties we associate with an equal energy particle. For example, it has the same relativistic inertia, the same relativistic energy, and the same relativistic length contraction. These particle-like properties logically extend to the quantized wave model of fermions, which will be presented later.

7. Quantized angular momentum

An electron exhibits properties of a rotating object, such as precession and a magnetic moment. However, if an electron is assumed to be a point particle, it is impossible for it to have a physical angular momentum of $\hbar/2$. Students are taught an electron has an "intrinsic" property of "spin." The word "intrinsic" implies that this is not physical rotation, and students should not attempt to understand it conceptually. However, *the Einstein-de Haas experiment proves that reversing an electron's spin with a magnetic field imparts physical angular momentum to a ferromagnetic rod.* [35]. For example, in iron, 96% of the observed angular momentum transfer to the iron rod is due to reversing the angular momentum of 96% of the electrons. The other 4% of the angular momentum transferred to the rod is due to a partial reversal of orbital angular momentum [36]. The point is there is experimental proof that reversing the electron's spin direction imparts physical angular momentum to a rod. Claiming that an electron possesses "intrinsic spin" requires the assumption there must be a non-rotational form of angular momentum that can be converted to a physically rotating iron rod. The quantized wave model of an electron does not require this assumption. The rotating wave with ω_c frequency and L_p amplitude possesses $\hbar/2$ physical angular momentum. The Einstein-de Haas experiment has conservation of angular momentum.

After generations of physicists have been taught that "spin" does not imply physical rotation, this new model needs additional support. Molecules can serve as a bridge to accepting quantized physical rotation as a fundamental property of nature. A carbon monoxide (CO) molecule is used as an example of any individual molecule isolated in space. The two atoms of CO have a nuclear separation of about 10^{-10} m. These two atoms have charge separation, so the rotation of this molecule produces an emission or absorption spectrum at microwave frequencies.

An isolated CO molecule *never* stops rotating. Even in its lowest energy state, it has about 3.8×10^{-23} J of ZPE in the form of a physical rotation with $\hbar/2$ quantized angular momentum corresponding to a 57 GHz rotation. This microwave frequency is never emitted (observable) because it is the CO molecule's ZPE. The observable absorption and emission frequencies are at 115 GHz or integer multiples of this frequency. These correspond to the CO molecule changing integer multiples of $\hbar$ angular momentum. An isolated CO molecule cannot be forced to rotate with some non-integer angular momentum such as $0.7\hbar$. What enforces this?

To answer this question, we will switch to the example of a superfluid. When angular momentum is introduced into a superfluid such as a Bose-Einstein condensate, the bulk superfluid does not rotate. Instead, the superfluid quantizes angular momentum into discrete, physically rotating vortices. Each micro-vortex possesses $\hbar$ quantized angular momentum [37], which have been photographed [38, 39]. A quantum vortex exhibits particle-like properties in the superfluid.

The universal field model is a perfect superfluid which has Planck's constant ħ as a physical property derived from Planck length $(\hbar G/c^3)^{1/2}$ fluctuations at Planck frequency. The superfluid universal field enforces the limitation that a wave-based CO molecule can only rotate with ħ/2 angular momentum in its ZPE energy state or additional integer multiples of ħ angular momentum in its rotationally excited states.

Quantization of angular momentum is the key ingredient required to give particle-like properties to the quantized wave model of a fundamental fermion. A wave propagating at the speed of light has no frame of reference. However, a wave rotating around a central point has a specific frame of reference. This means a rotating wave has both wave and particle properties. A rotating wave is confined energy which acquires inertia (rest mass). Quantized angular momentum is the "excitation" that converts a portion of the universal field into a fundamental fermion.

8. Electron model

8.1 Energy calculation

We are now going to attempt to build an electron from the properties of the universal field. For this task, we will adopt the following six starting assumptions.

1) The universal field exists as previously described exhibiting the calculated impedance.
2) Introducing a unit of quantized angular momentum into the universal field is the excitation, which creates all leptons and quarks as rotating waves in the universal field.
3) An electron is a quantized rotating wave in the universal field.
4) The electron model must be capable of generating an electron's de Broglie wave properties. This requires spherical standing waves with an electron's Compton frequency/wavelength.
5) Introducing a unit of quantized angular momentum into the chaotically fluctuating universal field creates a chaotically rotating wave with an amplitude of Planck length/time.
6) The rotating wave can be thought of as being one Compton wavelength $\lambda_c = 2.42\times10^{-12}$ m in circumference. This circle has a "Compton radius r_c" equal to one Compton angular wavelength $\lambda\!\!\!^{-}_c = r_c = \hbar/mc$. The quantized wave extends beyond this radius, but calculations assume this mathematical radius.

These assumptions are sufficient to approximately calculate the implied energy and angular momentum of this quantized wave-based electron model. We start with the energy calculation to determine if the model is plausible. In plausibility calculations, numerical constants near 1 are assigned the designation k and ignored in approximations. Equation (2) gives the energy density (U) of a wave $U = A^2\omega^2 Z/c$. The energy of a wave in volume V is $E = UV$. In the assumptions, the volume scales with wave properties: $V = k(c/\omega_c)^3 = kr_c^3$. In this, ω_c and r_c are an electron's Compton angular frequency and angular wavelength, respectively. Here is a list of the terms used in the following calculation.

$A = L_p = (\hbar G/c^3)^{1/2}$ amplitude = Planck length
$\omega = \omega_c = m_e c^2/\hbar$ frequency = electron energy/ħ
$V \approx k(c/\omega_c)^3 = k\lambda\!\!\!^{-}_c{}^3 = kr_c^3$ quantized wave volume
$Z_D = c\omega_c^2/G$ displacement impedance

$$E = UV = \frac{kA^2\omega^2 Z}{c}V = \frac{k}{c}\frac{\hbar G}{c^3}\omega_c^2\frac{c\omega_c^2}{G}\frac{c^3}{\omega_c^3} = k\hbar\omega_c \quad (20)$$

Making the substitution $\omega_c = 7.76\times10^{20}$ rad/s into Eq. (20) generates an electron's internal energy $E_i = k\hbar\omega_c = k\,8.19\times10^{-14}$ J. Therefore, this model has demonstrated plausibility. It is conceptually understandable why $E = mc^2$. Equation (20) arrived at this energy using $Z_D = c\omega^2/G$ impedance, kr_c^3 volume, L_p amplitude, and rotational speed of c.

The idea that the quantum vacuum has a physical property with units of 10^{113} J/m³ has been rejected by many scientists. It has been called "the worst theoretical prediction in the history of physics." [7] However, 10^{113} J/m³ of quasi-energy density implies that the quantum vacuum has the ability to create any fundamental fermion. The excitation is a ħ/2 unit of quantized angular momentum. This forms a rotating wave with undetectable Planck length amplitude. Fundamental fermions made this way should exhibit mysterious properties such as wave-particle duality and appear to have no physical volume.

Next, we will calculate the approximate angular momentum of the wave-based electron model just calculated. A wave propagating at the speed of light has momentum $p = E/c$. If this wave is confined to only propagate in a narrow circular channel with radius $r = r_c = \hbar c/E$, then the angular momentum would be analogous to hoop moment of inertia with $\mathcal{L} = pr = (E/c)(\hbar c/E) = \hbar$. However, this wave will later be characterized as an interference effect distributed over a volume. An interference effect can propagate faster than the speed of light. This does not violate the laws of

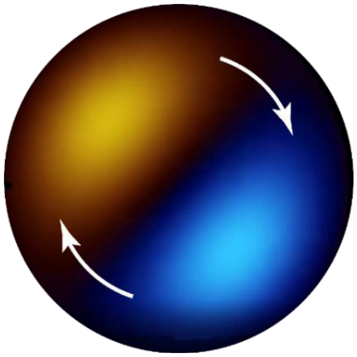

Fig 6. represents rotating distortions in the universal field that form an electron's core. The yellow and blue volumes represent spatial and temporal displacements. The black areas are a rotating rate of time gradient. All of these have energy density. A video demonstrating the electron's wave properties is available at www.quantizedwave.com/video-2

physics because an interference effect cannot transfer information or energy faster than light.

This rotation is also chaotic. This means that it has an expectation rotational axis, but all other rotation axes are present at reduced probability. This substantially reduces the net angular momentum to something less than ħ. We are only looking for approximations, so ħ/2 is plausible. A point particle approximation would have zero angular momentum. To summarize, we used the impedance of spacetime and a rotating wave with an amplitude of Planck length to generate both an electron's approximate energy and approximate angular momentum.

8.2 Model of an electron's core

The proposed electron model can be broken into two parts: the central core has more than 99% of the electron's energy and the external standing waves have less than 1% of the electron's energy. The external standing waves generate an electron's electric, magnetic, and gravitational fields. We will first discuss the model of an electron's core shown in Fig (6)

The electron's core has a mathematical radius (Compton radius) of $r_c = ƛ_c = 3.86 \times 10^{-13}$ m. This radius is used in calculations, but the rotating wave which forms the electron's core extends beyond this radius. For example, the electron's core shown in Fig 6 has been illustrated with a radius equal to ½ Compton wavelength (πr_c). There is no sharp boundary to the electron's core. Only the mathematical radius is precisely known.

The electron's core is a rotating wave with quantized angular momentum. This quantization causes the energy in the electron's core to respond as a single unit to a perturbation. For example, it transfers momentum only to a single quantized wave in a collision. This wave rotates with frequency $\omega_c = 7.76 \times 10^{20}$ rad/s and distorts spatial properties of the universal field with an amplitude of L_p.

Figure 6 shows two rapidly rotating distortions (designated "lobes") of the universal field. The arrows indicate the most probable rotation direction and axis. The universal field is a sea of Planck length/time fluctuations. The electron's core also has displacement amplitude of Planck length/time. This combination of a Planck length/time amplitude wave in a sea of Planck length/time vacuum fluctuations, means an electron's rotation is chaotic. It has an expectation rotational axis, but this is just the highest probability rotation. Other rotational axes also randomly occur at reduced probability relative to the expectation direction.

The yellow and blue lobes in Fig 6 represent different temporal and spatial distortions of the universal field. For example, the yellow lobe is assigned to have a slower rate of time than the blue lobe. The center of the yellow lobe loses one unit of Planck time (~5.4×10^{-44} s) every $1/\omega_c = 1.29 \times 10^{-21}$ seconds relative to the local rate of time. Therefore, it loses 4.18×10^{-23} seconds per second compared to the rate of time for the volume of space if the electron is removed. The yellow lobe also has spatial distortion relative to the local norm. The proper distance between two stationary points separated by r_c is increased by L_p compared to the local norm when the yellow lobe is removed.

The blue lobe has the opposite distortions. The rate of time is faster than the local norm by 4.18×10^{-23} seconds per second at the center of the blue lobe. Therefore, the yellow and blue lobes have slightly different rates of time. To put this in perspective, this rate of time difference is so small that the accumulated time difference between an electron's two lobes is about 40 microseconds over the age of the universe.

The blue lobe also has the opposite spatial distortion. The distance between stationary points separated by r_c decreases by L_p. To achieve these temporal and spatial gravitational distortions would require the hypothetical gravitational distortion of a distributed cloud of *negative* Planck energy. For example, a cloud of hypothetical negative energy would cause the rate of time to increase relative to the local norm. Also, the negative energy cloud would cause the distance between stationary points to decrease. There is no negative energy. This is just a hypothetical example.

The black areas in Fig 6 are displacement nulls. However, they have the maximum strain (maximum slope). This means the black areas are a rate of time gradient that is rotating at ω_c. Therefore, the black areas also have energy density.

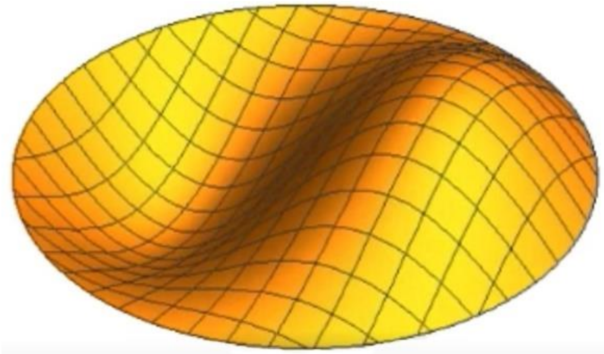

Fig 7. represents an electron's core as a Z-axis distortion of an elastic membrane. A Planck length expansion and contraction of volume is represented by the hill and valley depicted.

In Fig 1, vacuum fluctuations were represented as surface distortions of an elastic membrane. To illustrate the electron's core, we will average out these high-frequency background L_p fluctuations. This will be illustrated as a flat elastic membrane if no electron is present. Now imagine we introduce a rotating quantized wave (an electron) into this elastic surface. This way of illustrating the distortion produced by an electron is shown in Fig 7. We represent the region with a Planck length expansion (yellow in Fig 6) as a hill and a Planck length contraction (blue in Fig 6) as a valley in the elastic membrane. The hill and valley in Fig 7 can also represent slow and fast rate of time distortion.

In 1930, Erwin Schrodinger [40] analyzed the Dirac equation and derived a prediction that an electron should exhibit a fluctuating interference between positive and negative energy states. An electron should appear to have a jittery motion, which he designated "zitterbewegung" in German. Paul Dirac explained in his 1933 Nobel Prize lecture [41], "As a result of this oscillatory motion, the velocity of the electron at any time equals the velocity of light." In the article *On the Zitterbewegung of the Dirac Electron* [42], Kerson Huang states, "Zitterbewegung may be looked upon as a circular motion about the direction of the electron spin, with a radius equal to the Compton wavelength (divided by 2π) of the electron."

The summary previously given of the electron model was "The two lobes which form the electron's core are positive and negative energy distortions chaotically rotating at the speed of light in a volume with Compton radius r_c." *This fulfills many of the physical interpretations of the Dirac equation. The two rotating lobes can be interpreted as zitterbewegung (jittery motion) at twice the electron's Compton frequency.*

8.3 The source of an electron's fields

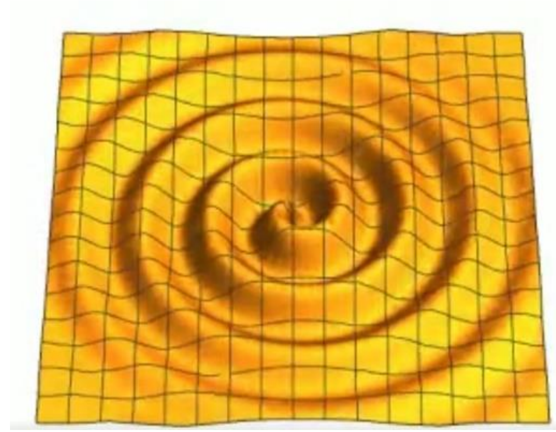

Fig 8. shows an Archimedean spiral as a sinusoidal distortion of an elastic membrane.

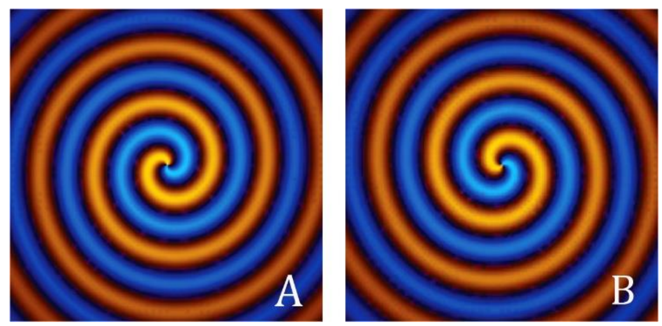

Fig 9. A & B both represent clockwise rotating sinusoidal Archimedean spirals. Figure 9A is outgoing waves and Fig 9B is incoming spiral waves.

Now, we are going to move on to describe another part of the electron model. If we actually had a rotating hill and valley on an elastic membrane, it would also create a propagating wave disturbance in the surrounding area of the elastic membrane. This is illustrated in Fig 8. The waves would move away from the source at the speed of surface wave propagation. Figure 8 does not show the source of the waves. These emanating waves would form the wave pattern that is an expanding Archimedean spiral shown in this figure. If the elastic membrane has a circular boundary that reflects these waves back towards the source, the reflected waves will also form a sinusoidal Archimedean spiral wave propagating back towards the source. The combination would produce a rotating interference pattern.

Figure 9A is another way of representing the distortions of Fig 8. The hills are yellow, and the valleys are blue. Figure 9A depicts waves propagating out from the source, and Fig 9B represents reflected waves propagating towards the source. This inward propagation creates a spiral that intuitively appears to have an opposite rotation. However, both figures are rotating

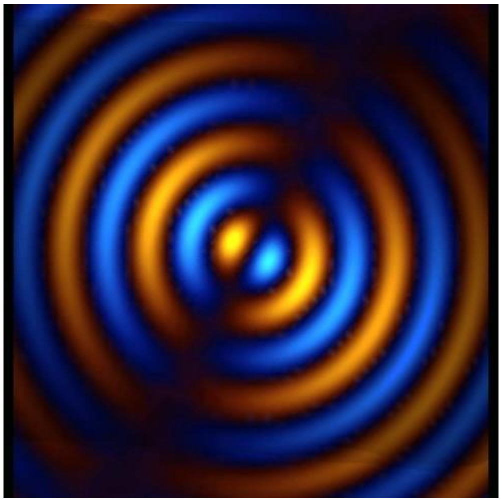

Fig 10. is the rotating electron model created by the superposition of Fig 9A and 9B. This model consists of the yellow and blue core lobes (± L_p and T_p distortions of the universal field) and a cloud of rotating standing waves which generate an electron's electric and gravitational fields. A short video animating about an electron's forces is available at www.quantizedwave.com/video-3

clockwise at the electron's Compton frequency ($\omega_c \approx 7.8 \times 10^{20}$ rad/s).

The superposition of outgoing and incoming waves of Fig (9A, 9B) forms the rotating interference wave pattern depicted by Fig 10 and 11. These two figures are taken together because they are two different ways of illustrating the result of combining Fig 9A and 9B. Even the two central lobes shown in Fig (6, 7) are generated by the superposition of counter-propagating Archimedean spirals of Fig (9A, 8B). The electron's core is approximated by the yellow and blue rotating lobes at the center of Fig 10. The wave amplitude beyond the core should decrease with $1/r$. However, a lesser decrease in amplitude is depicted in the next figures to better illustrates the external waves.

Figure 10 is drawn to emphasize the spatial amplitude. This way of depicting the electron model has the black areas as nulls with spatial distortion near zero. However, as previously stated, the black areas have the maximum strain which is the maximum slope. The rotating rate of time gradient in the black areas also has energy density. Therefore, combining the spatial and temporal portions of this model soothes out energy density. The energy density decreases with $1/r$ outside the core ($r > r_c$), but the distribution inside the core has not been determined. The core is defined by the volume where instantaneous internal communication happens.

The electron's mathematical radius (Compton radius) is not shown. It is an imaginary circle which passes approximately through the yellow and blue lobes. The circumference of this imaginary circle is one

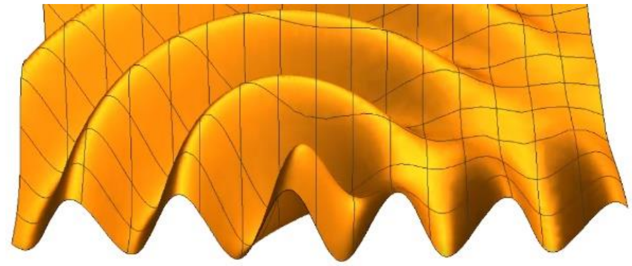

Fig 11. This is a 3-dimensional representation of the rotating standing wave that forms the electron model. This figure is cross sectioned through the middle of this model to reveal the sinusoidal standing waves. The amplitude of these waves should decrease with $1/r$ for $r > r_c$.

Compton wavelength ($\lambda_c/2\pi = r_c$). When this interference pattern rotates at the electron's Compton frequency ($\sim 10^{20}$ Hz), all the parts of the interference pattern outside the electron's Compton radius (r_c) are moving faster than the speed of light. Two overlapping waves often create *interference patterns* that move faster than *c*. This does not violate the laws of physics because information cannot be transmitted faster than *c* by interference effects.

Figure 11 is cross sectioned through the rotational axis to illustrate the sinusoidal standing wave properties. The $1/r$ decrease in wave amplitude external to the core is not illustrated. The rotating standing waves outside the electron's core have displacement amplitude less than Planck length. *Waves in the universal field cannot have a wavelength less than L_p, but distortions such as the rotating standing waves can have displacement amplitude less than L_p.*

An Archimedean spiral was used to generate Fig (9 - 11). The equation for an Archimedean spiral in polar coordinates is $r = a\theta$. In this equation, θ is the angle in radians, and "*a*" is a scaling factor with units of length. *The electron model used for illustrations is based on an Archimedean spiral with the equation $r = r_c\,\theta$.*

8.4 Resonant reflection of waves

The computer simulations assumed the inward propagating waves were created by an unseen spherical reflector. However, rather than a single external reflector, the reflection in the model of an electron is assumed to be the result of resonance with the universal field in which rotating standing waves in Fig 10 become their own reflectors. Waves attempting to escape are returned to the core with the proper phase.

In Bragg reflection, EM waves in a transparent medium reflect off externally generated acoustic waves. In stimulated Brillouin scattering, an intense laser beam creates acoustic waves in a transparent medium without requiring an external source. These acoustic waves then reflect the laser beam in the opposite direction. Both examples involve two different types of waves (acoustic and EM waves).

The simplest type of resonant reflection would be for a wave to create a density variation (like a multilayer dielectric reflector) that reflects the same wavelength. An ideal gas cannot achieve this type of acoustic wave resonance because it has a single speed of sound and has no nonlinearities. However, a quantized wave propagating in the universal field has many properties not shared with ordinary acoustic waves. For example, entangled photons have two different speeds – propagation at the speed of light and entanglement communication at infinite speed. The proposed electron model is a single quantized wave that must also have both speeds of internal communication. Changes in the electric and gravitational fields propagate with the speed of light, but the transfer of quantized angular momentum happens at superluminal entanglement speed. These two different speeds of communication are probably an important component of the wave reflection mechanism required to create the inward propagating waves.

8.5 Electron's point particle properties

Collision experiments indicate an electron is smaller than about 10^{-18} m. However, the energy in an electron's electric field is clearly part of an electron's total energy. This electric field energy is detectable beyond 10^{-6} m – a trillion times larger than 10^{-18} m. Also, an electron's electric field is incompatible with the 10^{-18} m size in another way. The energy in an electric field external to a radial distance r from charge e is: $E_{ext} = \alpha\hbar c/2r$. If an electron is assumed to have a radius of about 10^{-18} m, then the energy in the charge e electric field external to 10^{-18} m is about 1.2×10^{-10} J. This is an impossible 1400 times bigger than the electron's annihilation energy (8.2×10^{-14} J). Therefore, an electron model must explain how it appears to be both a point particle in collision experiments and explain the distributed energy in an electron's electric field. Finally, a particle 10^{-18} m in radius cannot have $\hbar/2$ physical angular momentum.

The wave-based electron model solves all these problems. It has a mathematical radius equal to the electron's Compton radius of $r_c = 3.86\text{x}10^{-13}$ m. Inserting $r = r_c$ into $E_{ext} = \alpha\hbar c/2r$, results in about 0.36% of an electron's total energy is in its electric field external to r_c. There is perhaps a comparable amount in the magnetic field. This is rounded off by saying more than 99% of the electron's energy is in the rotating core, and less than 1% is in its electric/magnetic field external to r_c. A mathematical radius of r_c is also compatible with $\mathcal{L} = \hbar/2$ as previously shown. The undetectable L_p wave amplitude and $\hbar/2$ quantized angular momentum combine to give the appearance of a point particle with zero radius. Therefore, this model appears to have no radius in a collision, have a cloud-like electric field energy and have physical angular momentum.

It is difficult to appreciate how small the electron's displacement amplitude (L_p) is compared to the electron's Compton radius. Suppose we imagine enlarging the electron's Compton radius by about 10^{19} times to equal the radius of the earth. Enlarging the electron's wave amplitude (L_p) by the same 10^{19} times means the electron's displacement amplitude would still be smaller than a proton ($L_p\times10^{19} \approx 10^{-16}$ m).

Next, imagine an electron and a positron "colliding." Except we imagine them as earth size rotating waves, each with displacement amplitudes of $\sim 10^{-16}$ m. If they were classical waves, they should merely pass through each other without noticing. However, they both possess quantized angular momentum. This quantized angular momentum makes these weak, and diffuse rotating waves have a probability of interacting as a quantized unit.

An electron and proton are also just weak waves that can sometimes pass through each other without colliding. The electron's quantized $\hbar/2$ unit of angular momentum interacts all or nothing. In the same way that two entangled photons respond faster than the speed of light, so also a energetic electron can collapse faster than the speed of light and interact with an individual quark in a proton. For example, a quantized wave-based electron can probe the internal quark structure of a proton. If a 50 GeV electron collides with a proton, the 50 GeV kinetic energy momentarily increases an electron's internal energy (frequency) by a factor of about 100,000. Giving an electron's $\hbar/2$ quantized angular momentum this additional energy causes it to increase rotational speed and decrease its radius to about 10^{-18} m. This more energetic electron can momentarily probe the internal structure of a proton.

This property of quantized angular momentum also explains the mysteries of an electron passing through a double-slit experiment. If the electron's wave structure encounters a double slit, the only possibility is that either 100% or 0% of an electron's quantized angular momentum will pass through both slits. Quantized angular momentum does not allow an intermediate value. Those lucky electrons which achieve 100% transmission of quantized angular momentum emerge on the other side of the double slit, and initially, they do not have the wave structure shown in Fig 10. They initially appear to be two disconnected waves, but they possess the key ingredient of ħ/2 quantized angular momentum. As they propagate away from the double slit, they gradually reform the counter propagating Archimedean spirals with ħ/2 angular momentum. This results in the mature wave structure shown in Fig 10.

After passing through the double slit, each wave-based electron strikes a broad area of the target. However, then the electron's quantized angular momentum causes a collapse into a single atom where it converts to the wave structure of a bound electron. However, multiple electrons produce a distribution of points characteristic of the electron's de Broglie waves passing through the double slits.

9. ZPE and virtual particles

Equations (1 to 5) show how the impedance of spacetime was derived from the spectral energy density of ZPE and the assumption that Planck length vacuum fluctuations cause this ZPE. This spectral energy density is derived from multiple harmonic oscillators at predominantly Planck frequency combining to also produce lower frequency L_p fluctuations. Does this model also explain how the energy of zero-point oscillators is $E_Z = \hbar\omega/2$?

$$E = UV = \frac{kA^2\omega^2 Z}{c} V = \frac{k}{c}\frac{\hbar G}{c^3}\omega^2 \frac{c\omega^2}{G}\frac{c^3}{\omega^3} = k\hbar\omega \quad (20A)$$

To examine this question, we repeat Eq. (20) (designated Eq. (20A)) but reinterpret the terms. The energy (E) of a harmonic oscillator is obtained by multiplying a wave's energy density from Eq. (2) $U = kA^2\omega^2 Z/c$ by the volume (V) of a harmonic oscillator $V = k\lambda\!\!\!^{-3} = k(c/\omega)^3$. Other substitutions include $A = L_p$ and $Z = Z_D$. The result is $E = k\hbar\omega$. This would match the desired result of $E_Z = \hbar\omega/2$ if $k = ½$. We have been making approximations by ignoring numerical constants near 1. Therefore, this result is approximately correct.

If electrons and positrons are modeled as point particles, virtual particles must be formed as matter-antimatter *pairs*. However, the wave-based model of electrons and positrons offers a different possibility. Suppose a fluctuation of the quantum vacuum creates a distortion of the universal field shown in Fig (6, 7), except with no rotation. This would have the potential of becoming either an electron or a positron if it had spin. However, without spin, this single fluctuation is both a virtual electron and a virtual positron. It is a superposition of both.

Now suppose there is a strong magnetic field present. If the magnetic field vector is towards us, then from our vantage point, an electron would appear to rotate clockwise, and a positron would appear to rotate counterclockwise. If the wave-based virtual electron-positron formed in this magnetic field, the 2 lobes would begin to split into 2 pairs of lobes, which would begin to rotate in opposite directions. This fluctuation lacks the ħ/2 quantized angular momentum to be stabilized and have a specific frame of reference. Therefore, the deception dissipates in a time of $1/\omega_c \approx 1.3\times10^{-21}$ s, and this effect redistributes itself back into the universal field. In this short time, and using currently available magnetic field strengths, the lobes merely become slightly distorted. Then they dissipate. This distortion is the magnetic polarization of the quantum vacuum. The ease with which this model of the universe explains virtual particles gives additional support to the model.

10. Electron's electric charge

The rotating standing wave cloud external to the two central lobes depicted in Fig 10 contain less than 1% of the electron's energy. However, these standing waves are very important because they create an electron's 1) de Broglie waves 2) electric/magnetic field, and 3) gravitational field. Even the currently accepted point particle model of an electron has most of an electron's energy in the central "point particle," and a smaller percentage of the electron's energy is in the surrounding electric and magnetic fields. The difference is that the wave-based model has a quantifiable structure that generates an electron's electric and gravitational fields from these standing waves. This section analyzes this statement.

An electron's core is a rotating wave in the universal field. *The displacement amplitude of this wave is L_p, and the dimensionless strain amplitude inside the core is L_p/r_c = 4.18×10^{-23}. To simplify the description of the external standing wave cloud, it is also useful to define $A_r \equiv L_p/r$ as the fundamental strain amplitude at arbitrary radius r.* An electron's electrical and gravitational properties are measured external to the core. Therefore, variations of $A_r \equiv L_p/r$ should create the equations which quantify an electron's electrical and gravitational properties.

We will start by demonstrating the connection between $A_r \equiv L_p/r$ and an electron's electrical properties. To make the connection to dimensionless L_p/r, we must convert the equation for charge e electrical potential $\mathcal{V}_e = (e/4\pi\varepsilon_o r)$ with units of volt into a dimensionless number. This is accomplished by dividing the electrical potential for charge $e = (\alpha 4\pi\varepsilon_o\hbar c)^{1/2} = 1.60\times10^{-19}$ C by Planck voltage $\mathcal{V}_p = (c^4/4\pi\varepsilon_o G)^{1/2} = 1.04\times10^{27}\ \mathcal{V}$. Also, Planck charge $Q_p = (4\pi\varepsilon_o\hbar c)^{1/2} = 1.88\times10^{-18}$ C and the fine structure constant $\alpha = e^2/4\pi\varepsilon_o\hbar c \approx {}^1/_{137}$ are used.

$$\frac{\mathcal{V}_e}{\mathcal{V}_p} = \left(\frac{e}{4\pi\varepsilon_o r}\right)\left(\frac{4\pi\varepsilon_o G}{c^4}\right)^{1/2} = \sqrt{\alpha}\,\frac{L_p}{r} = \sqrt{\alpha}\,A_r \qquad (21)$$

$$\frac{\mathcal{V}_E}{\mathcal{V}_p} = \left(\frac{Q_p}{4\pi\varepsilon_o r}\right)\left(\frac{4\pi\varepsilon_o G}{c^4}\right)^{1/2} = \frac{L_p}{r} = A_r \qquad (22)$$

Equation (21) converts $\mathcal{V}_e$, the electrical potential of charge e to dimensionless natural units, and Eq. (22) converts $\mathcal{V}_E$, the electrical potential for Planck charge Q_p to dimensionless units. Planck charge is the fundamental unit of charge generated from fundamental constants ε_o, ħ, and c. The wave in the electron's core with amplitude L_p is attempting to generate standing waves external to the core with strain amplitude (slope) $A_r = L_p/r$. However, this amplitude interacting with the universal field would generate the voltage, electric field and force of Planck charge. It is a prediction of this model that the electron's rotating core is attempting to generate Planck charge, not charge e. There is an effect at the core's edge which prevents $1 - \alpha^{1/2} \approx 91.5\%$ of the first order wave from being emitted and forming standing waves external to the core. Without this effect, an electron would theoretically have Planck charge (Q_p). With this effect, an electron has charge $e = \alpha^{1/2}Q_p$. The cause of this is unknown and becomes part of the mystery associated with the fine structure constant. This effect will be designated "vacuum polarization" but this is just a name for the reduced amplitude that results in the fine structure constant (α) appearing in equations. Therefore, equations incorporating charge e will be shown to need α or $\alpha^{1/2}$ to offset the effect of vacuum polarization. The nonlinear waves that generate the electron's gravitational properties are not affected by this "vacuum polarization".

In this model, electrical potential has the properties of slope. For example, Eq. (21) shows the magnitude of the slope produced by an electron at distance r is $\alpha^{1/2}L_p/r$. Another electron considers this distortion to be a polarized length slope. To an electron or positron, the distance propagating towards charge e appears to be slightly different than the distance propagating away from charge e. A wave that is rotating about 10^{20} Hz feels this difference and wants to migrate either towards or away from the source of the charge.

$$\frac{\mathcal{E}_e}{\mathcal{E}_p} = \left(\frac{e}{4\pi\varepsilon_o r^2}\right)\left(\frac{4\pi\varepsilon_o\hbar G^2}{c^7}\right)^{1/2} = \alpha\left(\frac{L_p}{r}\right)^2 = \alpha A_r^2 \qquad (23)$$

The electric field produced by charge e at distance r is $\mathcal{E}_e = e/4\pi\varepsilon_o r^2$. Equation (23) converts this to dimensionless natural units by dividing by Planck electric field $\mathcal{E}_p = (c^7/4\pi\varepsilon_o\hbar G^2)^{1/2} = 6.5\times10^{61}\ \mathcal{V}$/m. The result is $\alpha(L_p/r)^2 = \alpha A_2^2$. Electric field, with units $\mathcal{V}$/m, is the rate of change of electrical potential.

It has been postulated that an electron's Compton frequency is a resonant frequency that eliminates loss and stabilizes the rotating wave that forms an electron's core. External to the core, there appears to be both a non-oscillating and an oscillating distortion of the universal field. The non-oscillating component creates what we perceive as the electron's electric field. The oscillating component will be discussed later.

$$\frac{F_E}{F_p} = \left(\frac{Q_p^2}{4\pi\varepsilon_o r^2}\right)\frac{G}{c^4} = \left(\frac{L_p}{r}\right)^2 = A_r^2 \qquad (24)$$

$$\frac{F_e}{F_p} = \left(\frac{e^2}{4\pi\varepsilon_o r^2}\right)\frac{G}{c^4} = \left(\sqrt{\alpha}\,\frac{L_p}{r}\right)^2 = \alpha A_r^2 \qquad (25)$$

Equation (24) gives the electrostatic force between two Planck charges in dimensionless Planck units (F_E/F_p). Equation (25) gives the force between two charge e fermions in dimensionless Planck units (F_e/F_p). Both equations are Coulomb's law divided by Planck force $F_p = c^4/G$. Planck force is a fundamental constant representing the largest force spacetime can generate. For example, Planck force is approximately the force between two merging black holes. It should be noted that Eq. (23) and Eq. (25) both equal αA_r^2. However, this is a dimensionless number that takes on a different meaning when dimensions are added.

Even though Eqs. (21 – 25) correctly state the magnitudes of electrical potential, electric field, and electrostatic force, the model is still incomplete. In particular, the model currently does not identify the structural difference between an electron and a positron. The model also needs to be developed further to add the correct vectors to the electromagnetic force equations.

11. Electron's gravity

The real challenging test is whether the universal field model can generate gravitational curvature and force. GR does not describe how a fundamental fermion creates curved spacetime or force at a distance. Is it possible that the standing waves have another component that creates an electron's gravitational field? The gravitational force magnitude between two electrons is roughly 10^{43} times smaller than the electrostatic force between two electrons. We will explore the possibility that standing waves create both effects. An electron's electric field would be a first-order effect and gravity would be a second-order, nonlinear effect.

If the universal field were infinite and perfectly homogeneous, it would have no resonances, no boundaries, and no nonlinearities. However, the very description of the universal field implies that Planck frequency is the maximum allowed frequency, and Planck length is the boundary for the minimum allowed wavelength. This is a single boundary condition expressed in two different ways. This boundary implies the universal field must exhibit nonlinearities even for frequencies much less than Planck frequency ω_p and wavelengths much longer than Planck length L_p.

When sound is transmitted through an acoustic medium, nonlinearities are introduced by the finite properties of the medium. For example, when sound waves propagate in air, nonlinearities occur which modify the original waveform. This is not noticeable at conversational levels. However, nonlinearities are observable for intense ultrasonic sound. An acoustic wave in air is a pressure wave. The high-pressure portions of the wave have different properties than the low-pressure portions. This results in nonlinear effects.

The universal field is modeled as a simple homogeneous acoustic medium. The only component is Planck frequency vacuum fluctuations with amplitude of Planck length/time (approximates). Waves in this medium would encounter the dominant boundary condition set by the maximum frequency (minimum wavelength). This boundary means the universal field should be a nonlinear medium. Waves of any frequency propagating in this medium should exhibit a nonlinear distortion. *The following hypothesis is tested: The universal field is a nonlinear medium. The same rotating core wave that produces the electric field standing wave structure, also produces a much weaker nonlinear standing wave which is the electron's gravitational field. If this is correct, gravitational effects should scale with standing wave strain amplitude squared (A_r^2).*

This testable hypothesis is an extrapolation from known nonlinear effects produced in transparent materials by intense laser beams. This is a mature scientific field known as "nonlinear optics." A short description of nonlinear optics will be given next. Then we will return to a discussion of gravity.

The atoms and molecules which form transparent materials have electron orbitals that can be distorted by an imposed electric field. Crystals have molecular symmetry and exhibit the greatest variety of electro-optic effects. However, all transparent materials (all solids, liquids, and gasses) exhibit a nonlinear effect known as the Kerr effect. In this effect, the index of refraction changes with the square of the electric field ($\mathcal{E}^2$). This happens with both DC and AC electric fields.

Even the electric field of light produces a change in the index of refraction. This is known as the "optical Kerr effect" or "AC Kerr effect." For example, a laser beam propagating in glass with intensity in the range of 1 GW/cm^2 will self-focus because the optical Kerr effect makes a refraction gradient that has the properties of a focusing lens. The connection to gravity makes an analogy to the optical Kerr effect.

$$\boldsymbol{P} = \chi^{(1)} : \boldsymbol{\mathcal{E}} + \chi^{(2)} : \boldsymbol{\mathcal{E}\mathcal{E}} + \chi^{(3)} : \boldsymbol{\mathcal{E}\mathcal{E}\mathcal{E}} + \ldots \quad (26)$$

$$n = n_o + \frac{3\chi^{(3)}}{2n_o} \left|\boldsymbol{\mathcal{E}}_\omega\right|^2 \quad (27)$$

Molecules have complex polarization properties. For example, a water molecule has an irregular shape with charge separation and the three atoms making a 104-degree angle. Therefore, tensors are required to describe the complex polarization properties of water or other molecules forming a transparent medium. Equation (26) is the general form of equations required to describe all nonlinear properties. In Eq. (26) ($\boldsymbol{P}$) is the total nonlinear polarization of the molecules of a transparent medium. This polarization is affected when EM radiation is present with electric field vectors $\boldsymbol{\mathcal{E}}_j$, $\boldsymbol{\mathcal{E}}_k$, and $\boldsymbol{\mathcal{E}}_l$. In this equation, $\chi^{(1)}$ is the linear susceptibility tensor, while $\chi^{(2)}$ and $\chi^{(3)}$ are second and third rank nonlinear tensors. Equation (26) applies to a broad range of nonlinear optics effects covered in standard texts on this subject [43]. Equation (27) is the special case of Eq. (26), which describes the optical Kerr effect. In Eq. (27), (n_o) is the zero-amplitude index of refraction, and (n) is the index of refraction when the electric field of EM radiation also is present. The important point is that the nonlinear component of the refractive index scales with the electric field squared $\mathcal{E}_\omega^2$ (amplitude squared). Even though this electric field is oscillating and reversing polarity, the electric field squared in Eq. (27) is always a positive value.

The gravitational effect in space has some similarities to a change in the index of refraction scaling with amplitude squared. The similarity to the optical Kerr effect is sufficient to test the possibility that the gravitational distortion produced by an electron might scale with strain amplitude squared. This squaring of strain amplitude would produce an extremely small distortion which has only one polarity. The square is always positive, and gravity only attracts.

The rotating wave that forms an electron's core has strain amplitude of L_p/r_c = 4.18x10^{-23}. Therefore, the square of the electron's strain amplitude within the core L_p^2/r_c^2 = 1.75x10^{-45} should be an electron's nonlinear strain amplitude. This is the predicted slope of the gravitational distortion within the core. Since the core has a mathematical radius of r_c, the predicted nonlinear distortion across this distance is $(L_p/r_c)^2 r_c = L_p^2/r_c$ = 6.76x10^{-58} m. *This predicted nonlinear distortion of an electron is physically correct and corresponds to an electron's true "gravitational radius"* $r_g = L_p^2/r_c = Gm_e/c^2$ = 6.76x10^{-58} m. This is also half an electron's Schwarzschild radius.

This ~10^{-57} m distortion is not measurable for an individual electron. However, this is the contribution each electron makes to the total gravitational curvature (distortion) produced by a large mass. *It is possible to have a distortion of the universal field, that is smaller than Planck length (~10^{-35} m), even though it is not possible to have a wavelength smaller than L_p.*

The concept of an electron's "gravitational radius" is useful because it defines the gravitational slope (curvature) at a distance greater than r_c. The gravitational distortion should decrease with $1/r$. *Therefore, the predicted slope of the gravitational curvature produced by an electron is* $r_g/r = L_p^2/r_c r$.

Now we will compare the gravitational distortion derived from the wave-based model to the curvature obtained from GR. The gravitational time dilation $dt/d\tau$ from the Schwarzschild solution to general relativity is $dt/d\tau = [1 - (2Gm/c^2r)]^{-1/2}$ where dt is the rate of time in zero gravity and $d\tau$ is the rate of time in gravity. The "r" term is circumferential radius from general relativity. However, for an electron's mass, the conventional radial distance r can be used. The gravitational time dilation from this model would be $dt/d\tau = 1 + r_g/r$.

$$\frac{dt}{d\tau} = 1 + \frac{r_g}{r} = 1 + \frac{L_p^2}{r_c r} = 1 + \frac{\hbar G}{c^3}\frac{mc}{\hbar r} = 1 + \frac{Gm}{c^2 r} \qquad (28)$$

Equation (28) shows this approximation converts to $dt/d\tau = 1 + Gm/c^2r$. This is the known weak field gravity approximation for gravitational time dilation. This is obtained from the Schwarzschild solution to GR. For an electron's mass (9.1x10^{-31} kg) and distance greater than r_c = 3.86x10^{-13} m, this approximation matches the exact solution from GR to better than 1 part in 10^{44}. This accuracy far exceeds the goal required for approximations. Therefore, an electron's gravity is successfully modeled as a nonlinear effect that scales with strain amplitude squared.

$$\frac{dt}{d\tau} = 1 + \frac{Gm}{c^2 r} = 1 + \mathcal{N}A_r^2 \qquad (29)$$

$$\frac{F_G}{F_p} = \left(\frac{Gm^2}{r^2}\right)\frac{G}{c^4} = \left(\mathcal{N}A_r^2\right)^2 \qquad (30)$$

Equations (29 and 30) returns to points being made previously in Eq. (21 – 25). Those equations showed that an electron's electrical potential, electric field, and electrostatic force can be expressed as a function of radial strain amplitude $A_r \equiv L_p/r$. The gravitational curvature Eq. (29) is analogous to the electrical potential Eq. (21, 22), except the electrical equations were first order, scaling with A_r, and the gravitational curvature Eq. (29) is a second-order effect which scales with amplitude squared (A_r^2). The gravitational force between two electrons in Eq. (30) adds an additional square, producing A_r^4.

Equations (29, 30) introduce a new term designated the "wave scaling number" $\mathcal{N} \equiv r/r_c = r/\lambda\!\!\!^{-}_c = mcr/\hbar$. This is the separation distance (r) between two electrons, expressed as the dimensionless number of Compton angular wavelengths $\lambda\!\!\!^{-}_c$ which equals the number of Compton radii. For electrons, $\mathcal{N} \equiv r/r_c \approx r/3.86\text{x}10^{-13}$ m.

12. Verified predictions

This section contains 8 equations that prove an electron's gravitational and electrostatic forces are closely related. But we will start with a brief review.

1) The quantum vacuum is assumed to have Planck length (L_p) vacuum fluctuations, predominantly at Planck frequency (ω_p). This forms a medium with quantifiable impedance that propagates waves at the speed of light.

2) This is a nonlinear medium with the properties of a "universal field". It forms everything in the universe, including other fields.

3) An electron's core is modeled as a wave in the universal field rotating at an electron's Compton frequency (~ 10^{20} Hz). This rotating wave has a) an undetectable displacement amplitude of Planck length b) $\hbar/2$ quantized angular momentum and c) mathematical

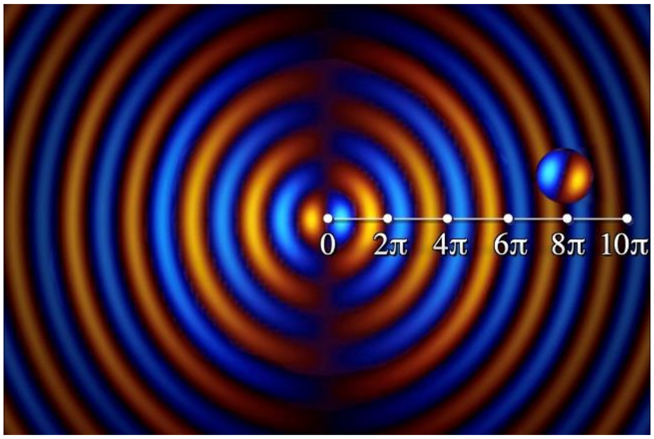

Fig 12. shows the standing wave cloud of the center electron overlapping a second electron's core (on right). The white dots are separated by one complete Compton wavelength or 2π Compton angular wavelengths $\bar{\lambda}_c = \hbar/m_e c$. Therefore, the dimensionless "wave scaling number $\mathcal{N} \equiv r/\bar{\lambda}_c = rmc/\hbar$" for this example is $\mathcal{N} = 8\pi \approx 25$.

radius equal to an electron's Compton angular wavelength $\bar{\lambda}_c = \hbar/m_e c = 3.86 \times 10^{-13}$ m.

4) This rotating core wave generates standing waves around the core. These standing waves form both an electron's electromagnetic and gravitational properties.

5) An electron's EM properties are a first order distortion of the universal field produced by the standing waves.

6) An electron's gravity is a nonlinear, second order effect that scales with strain amplitude squared.

Figure 12 shows an electron core centered on zero. It has a yellow lobe representing a distributed Planck length expansion of volume and a blue lobe representing a distributed Planck length contraction of volume. These opposite distortions represent a wave with $\hbar/2$ quantized angular momentum chaotically rotating around the central point. This rotating wave creates two types of standing waves (previously discussed) in the surrounding universal field. The first order effect creates the distortion we interpret as the electron's electric/magnetic field. There is also a much weaker, nonlinear standing wave, that creates the electron's gravitational field. The amplitude of both types of standing waves decreases with inverse distance.

The second electron core in Fig 12 is rotating in a distorted volume of the universal field created by the central electron's standing waves. This distortion causes the rotating wave to attempt to migrate. Preventing this migration results in a force on this rotating wave.

The following equations will use a new term which needs an explanation. In these equations, the electrostatic force magnitude (F_e) between two electrons or two muons (charge e) is always paired with the fine structure constant (α) in the form $\alpha^{-1}F_e \approx 137F_e$. This is because the wave with Planck length L_p amplitude in the electron's or muon's core should generate Planck charge Q_p, not charge e (previously explained). Charge Q_p is reduced to charge e by vacuum polarization at the edge of the core. Rather than always carrying the term $\alpha^{-1}F_e$ in charge e force equations, we will define and use a new term: $F_{e\alpha} \equiv \alpha^{-1}F_e \approx 137F_e$. This also simplifies the electrostatic force magnitude between two electrons from $F_e = e^2/4\pi\varepsilon_o r^2$ to $F_{e\alpha} = \hbar c/r^2$.

$$\mathbb{F}_{e\alpha} = \left(\mathbb{E}/\mathcal{N}\right)^2 \qquad (31)$$

$$\mathbb{F}_G = \left(\mathbb{E}^2/\mathcal{N}\right)^2 \qquad (32)$$

Equations (31, 32) reveal the simplicity and harmonious connection between an electron's or muon's electrostatic and gravitational forces. *To see this connection, Eq. (31, 32) incorporates the dimensionless wave scaling number* $\mathcal{N} = r/\bar{\lambda}_c = rmc/\hbar$. The other terms in Eq. (31, 32) are also dimensionless. The α adjusted electrostatic force between two electrons or muons in Planck units is, $\mathbb{F}_{e\alpha} \equiv \alpha^{-1}F_e/F_p = \hbar G/c^3r^2$. The gravitational force between two electrons or two muons in Planck units is, $\mathbb{F}_G \equiv F_G/F_p = (Gm/c^2r)^2$. The electron's or muon's energy, stated in Planck units is: $\mathbb{E} \equiv (E/E_p) = m(G/\hbar c)^{1/2}$. For electrons $\mathbb{E} = 4.18 \times 10^{-23}$. Both an electron's mass and Compton frequency also equal this dimensionless number in Planck units.

Written this way, Eq. (31 and 32) look nearly identical. The only difference in the right side of these equations is a square. However, this difference results in an electron's gravitational force $\mathbb{F}_G$ *being about* 10^{45} *times smaller than the* α *adjusted electrostatic force* $\mathbb{F}_{e\alpha}$*. Even though this is an enormous difference in magnitude, these two forces are obviously related.*

This relationship is not obvious on the macroscopic scale. The connection is only revealed through the inclusion of quantum mechanics. The single rotating wave at an electron's core generates first and second order standing wave distortions in the surrounding universal field. The first order standing waves create the distortion responsible for the electron's electrostatic force. The much weaker nonlinear standing waves, create an electron's gravitational force.

An electron's or muon's standing wave cloud decreases with $1/r$ but extends indefinitely. These standing waves distort the surrounding universal field. A quantized rotating wave such as the second electron in Fig 12 feels the effect of a distorted medium throughout its entire volume. No virtual messenger particles are required to find and transfer forces between corpuscular particles in this model.

The gravitational force between two muons in Eq. (32) is $207^2 \approx 43{,}000$ times stronger than the gravitational force between two electrons. However, muons and electrons both generate the same electrostatic force in Eq. (31). How is this accomplished? The following is a mathematical explanation. Later, a conceptual explanation will be given. When Eq. (31) applies to muons rather than electrons, the dimensionless energy $\mathbb{E}$ in the numerator increases by a factor of about 207. However, this difference is canceled by muons having a smaller Compton radius (shorter Compton angular wavelength $ƛ_c$). This causes $\mathcal{N}$ in the denominator to also increase by 207 – canceling the effect of mass/energy. Therefore, this explains how the electrostatic force between any two charge e particles in Eq, (31) can be independent of particle energy. Electric charge can be conceptually understood as the result of a particle's wave properties. This will be discussed in more detail later.

$$\mathbb{F}_G = \mathcal{N}^2 \mathbb{F}_{e\alpha}^2 \tag{33}$$

The original objective of this research was to see if it was possible to "invent" a wave-based model of an electron. There was no intention of modeling the electromagnetic and gravitational forces. However, just following logical steps, the wave-based electron model was generating both forces. Furthermore, the model was predicting that these forces should be related through a square exponent. The first support for this came from the special case of two hypothetical particles with an electron's mass but Planck charge. If the forces between these two hypothetical particles are extrapolated to a separation distance equal to their Compton radius ($r = r_c = ƛ_c = 3.86 \times 10^{-13}$ m), then the force relationship in natural Planck units is $\mathbb{F}_G = \mathbb{F}_E{}^2$. This equation eventually evolved into Eq. (33), applicable to electrons or muons at arbitrary separation distance. Equation (33) proves the predicted square exponent relationship between forces is correct.

To internalize Eq. (33), a numerical example will be given. Suppose two electrons are separated by 68 nm (nanometers). At this separation, $F_G = 1.2 \times 10^{-56}$ N. In Planck units, $\mathbb{F}_G = F_G/F_p = 10^{-100}$. The α adjusted electrostatic force at 68 nm is $F_{e\alpha} = \hbar c/r^2 = 6.8 \times 10^{-12}$ N. In Planck units $\mathbb{F}_{e\alpha} = F_{e\alpha}/F_p = 5.7 \times 10^{-56}$. At 68 nm, $\mathcal{N} = 1.76 \times 10^5$. Therefore, $\mathcal{N}\mathbb{F}_{e\alpha} = 10^{-50}$ and $\mathcal{N}^2\mathbb{F}_{e\alpha}{}^2 = 10^{-100} = \mathbb{F}_G$.

$$\frac{F_p}{\mathcal{N}F_{e\alpha}} = \frac{\mathcal{N}F_{e\alpha}}{F_G} \tag{34}$$

Equation (34) uses SI units to designate both the forces between electrons and Planck force. The key to making a connection between these very different force magnitudes is incorporating the wave scaling number $\mathcal{N}$. This not only compensates for the difference between electrons and muons, it also shows there is a symmetrical relationship between 1) Planck force F_p, 2) the α adjusted electrostatic force $F_{e\alpha}$, and 3) the gravitational force F_G.

The numerator on the left side is Planck force ($F_p = c^4/G \approx 1.21 \times 10^{44}$ N). This is a fundamental constant representing the strongest force that the universal field can generate. In natural units, Planck force is equal to 1 and is approximately the force exerted between two merging black holes. The denominator on the right side of Eq. (34) is F_G. This is the gravitational force between two electrons at arbitrary separation distance r. This is the weakest force between two charged particles at separation distance r. *Therefore, Eq. (34) incorporates two extremes – the strongest force in the universe (F_p) and the weakest force (F_G) between two charged particles at distance r.*

The key point of Eq. (34) is that on a logarithmic scale, $\mathcal{N}F_{e\alpha}$ (the electrostatic force F_e times $\mathcal{N}/\alpha$), is exactly midway between these two extremes of force. This relationship will be illustrated using the previous numerical example of two electrons separated by 68 nm. In natural Planck units, $\mathbb{F}_p = 1$. At this separation, $\mathbb{F}_G = 10^{-100}$. Exactly midway between these two extremes is $\mathcal{N}\mathbb{F}_{e\alpha} = 10^{-50}$. In SI units, $F_p = 1.2 \times 10^{44}$ N, $\mathcal{N}F_{e\alpha} = 1.2 \times 10^{-6}$ N and $F_G = 1.2 \times 10^{-56}$ N. Again, these are separated by a factor of 10^{-50}.

Both sides of Eq (34) equal c^2r/Gm which is dimensionless. If we invert this, we have Gm/c^2r which is the weak gravity curvature from general relativity.

$$F_G = \left(\frac{L_p}{ƛ_c}\right)^2 F_{e\alpha} \tag{35}$$

An introductory point at the start of this section was: *An electron's gravity is a nonlinear, second order effect that scales with strain amplitude squared.* Even though this refers to the strain amplitude of the standing waves external to the core, there are cancellations when forces are compared which reduce to the electron's core strain amplitude squared $(L_p/ƛ_c)^2 = 1.75 \times 10^{-45}$. Since $(L_p/ƛ_c)^2 = Gm^2/\hbar c$, the connection between the electron's electrostatic and gravitational forces is revealed by quantum mechanics.

There are three length terms associated with the wave-based electron model. These are an electron's Compton angular wavelength $ƛ_c$, its displacement amplitude L_p and its gravitational radius $r_g \equiv Gm_e/c^2 = 6.76 \times 10^{-58}$ m. An electron's gravitational radius r_g was previously discussed and illustrated by $dt/d\tau = 1 + r_g/r$. This way of expressing the gravitational time dilation curvature produced by an electron is accurate to better than 1 part in 10^{44} for an electron at distance $r > ƛ_c$. Note that $ƛ_c$ also equals an electron's Compton radius $r_c = ƛ_c = mc/\hbar = 3.86 \times 10^{-13}$ m.

$$\frac{r_g}{L_p} = \frac{L_p}{r_c} \tag{36}$$

Equation (36) shows an electron's three length terms (r_g, L_p and $ƛ_c$) have a symmetrical relationship. On a logarithmic scale of length, Planck length $L_p = (\hbar G/c^3)^{1/2} = 1.62 \times 10^{-35}$ m is exactly midway between an electron's gravitational radius $r_g = 6.76 \times 10^{-58}$ m and its Compton radius $r_c = 3.86 \times 10^{-13}$ m. This symmetry implies a type of harmony between an electron's gravitational radius, Planck length and an electron's Compton radius (also Compton angular wavelength $r_c = ƛ_c$).

This symmetry also applies to all particles, even baryons, if r_g and r_c are calculated from total mass. Particles more massive than an electron have a larger gravitational radius r_g and a smaller Compton radius r_c. These terms symmetrically scale, keeping L_p exactly in the middle for any mass fermion. These three lengths are equal at the limit of Planck mass $m_p = (\hbar c/G)^{1/2}$ where $r_g = L_p = r_c$. Both sides of Eq. (36) equal m/m_p.

The equation $r_g/L_p = L_p/r_c$ also says that a particle's gravitational radius is the inverse of its Compton radius when both are stated in Planck units. For example, in Planck units, an electron's gravitational radius is ($r_g/L_p = 4.18 \times 10^{-23}$) and ($L_p/r_c) = 4.18 \times 10^{-23}$ is the inverse of an electron's Compton radius in Planck units.

$$r_g = L_p^2 / ƛ_c \tag{37}$$

If we define quantum gravity as: "A theory that uses quantum mechanics to explain gravitational physics", then Eq. (37) meets this definition. This is a quantum gravity equation. The left side of Eq. (37) is r_g, an electron's gravitational radius. The right side of Eq. (37) is an electron's quantum mechanical wave properties, L_p and $ƛ_c$. These waves physically produce the nonlinear distortion of the universal field that we designate as gravitational curvature.

General relativity does not address the physics of how mass/energy causes the curvature of spacetime. Equation (37) is proposed to be a step towards a quantum gravity explanation of how wave-based particles cause the curvature of spacetime. The gravitational distortion of the universal field across an electron's core (ignoring EM effects) was previously shown to be a nonlinear effect scaling with an electron's strain amplitude squared $(L_p/r_c)^2$. This is multiplied by an electron's Compton radius r_c to generate the distortion across this radius. This gives an electron's gravitational radius: $r_g = (L_p/r_c)^2 r_c = L_p^2/r_c = L_p^2/ƛ_c = 6.76 \times 10^{-58}$ m. For example, an electron's gravitational time dilation can now be stated using quantum mechanical terms: $dt/d\tau = 1 + L_p^2/ƛ_c r$.

Equation (37) also applies to all hadrons. For example, a neutron is a composite particle formed by three quarks. However, neutrons generate de Broglie waves in a double slit experiment. This means that neutrons must generate external standing waves with a wavelength characteristic of their total mass/energy. Therefore, they have a Compton angular wavelength derived from their total mass. This is the neutron's Compton angular wavelength $ƛ_c$ that generates a neutron's gravitational radius in Eq. (37).

$$\frac{F_G}{F_{e\alpha}} = \frac{r_g}{r_c} = \frac{r_g^2}{L_p^2} = \frac{L_p^2}{r_c^2} = 1.75 \times 10^{-45} \tag{38}$$

Equation (38) states the relationship between an electron's force ratio ($F_G/F_{e\alpha}$) and the three length terms (r_g, L_p, and r_c) used to describe the wave-based electron's structure. These three lengths form ratios which also equal (1.75×10^{-45}).

The undisputed gold standard for testing a new physics theory is whether it makes correct predictions. Equations (31 – 38) *verify predictions derived from the universal field hypothesis.*

13. Oscillating components of fields

While Eq. (19, 21, 23, 25, and 30) are successful in describing some of an electron's electrical and gravitational properties, an important part of the model is being ignored. It is necessary to recognize that the electrical and gravitational properties also incorporate standing waves oscillating at $\omega_c = 7.76 \times 10^{20}$ rad/s. The need to recognize these oscillating components becomes obvious when we attempt to generate the energy density of an electron's electric field. An electric field $\mathcal{E}$ has energy density $U_\mathcal{E} = \frac{1}{2}\,\varepsilon_o\mathcal{E}^2$. The electric field produced by an electron at distance r is $\mathcal{E}_e = e/4\pi\varepsilon_o r^2$. Therefore, combining these and setting $e^2/4\pi\varepsilon_o = \alpha\hbar c$ yields $U_e = (1/8\pi)\,\alpha\hbar c/r^4$.

$$\frac{kA^2\omega_e^2 Z_s}{c} = \left(\frac{1}{8\pi}\right)\frac{\alpha\hbar c}{r^4} \tag{39}$$

$$A \equiv A_{eo} = \sqrt{\alpha}\,\frac{L_p r_c}{r^2} = \sqrt{\alpha}\,\frac{A_r}{\mathcal{N}} \tag{40}$$

Equation (39) equates the two energy density equations. We know every term except for the amplitude (A). Equation (40) is the solution for the oscillating amplitude (A_{eo}) required to achieve the electron's electric field energy density if the numerical constant is $k = 1/8\pi$. Note the difference between the oscillating amplitude $A_{eo} = (\alpha)^{1/2}A_r/\mathcal{N}$ and the non-oscillating amplitude $A_e = (\alpha)^{1/2}A_r$, which generates Eq. (21), the electron's electrical potential. These two amplitudes are equal at distance $r = r_c$ because $\mathcal{N} = 1$. This model is in its infancy, and it does not explain how these two amplitudes coexist.

The wave-based model is also predicting that the gravitational field produced by an electron probably also has an oscillating component. This oscillating component of a wave-based fermion's gravity has amplitude designated $A_{Go} = (L_p/r_c)^2/\mathcal{N}^2 = L_p^2/r^2$. Therefore, extrapolating from an electron's oscillating electric field amplitude, an electron's oscillating gravitational field amplitude should generate an extremely small energy density designated U_G. We will calculate the energy density magnitude in an electron's gravitational field.

$$U_G = \frac{kA_{Go}^2\omega_c^2 Z_s}{c} = k\left(\frac{\hbar G}{c^3 r^2}\right)^2 \omega_c^2\left(\frac{c^3}{G}\right)\frac{1}{c} \tag{41}$$

$$U_G = \left(\frac{1}{8\pi}\right)\frac{Gm_e^2}{r^4} \tag{42}$$

Equation (41) makes substitutions into Eq. (2) which is the energy density equation $U = kA^2\omega^2 Z/c$. Equation (42) sets $k = 1/8\pi$ and $m_e = \hbar\omega_c/c^2$. This is believed to be the first-time gravitational energy density has been derived from a fermion model.

Equations like Eq. (42) have been previously generated with the mass term being total mass m rather than individual fermion mass such as m_e. There is not universal agreement on the energy density of a gravitational field. For example [44] has 78 references representing several different conclusions about gravitational energy density.

The assumptions used to generate Eq. (42) do not indicate whether the mass term in Eq. (42) can be extrapolated to massive objects made of many fundamental fermions. The problem is that the oscillating components of many fundamental fermions must add coherently (in phase) for the square in the m^2 term to be applicable to the entire mass. Incoherent addition of waves results in a much smaller total energy density for a mass consisting of many fermions. However, the energy radiated by GWs seems to imply coherent addition of these waves.

Either way, the gravitational field produced by a quantized wave electron model has an energy density that extends over vast distances. Two widely separated electrons can experience gravitational attraction because each electron has an extended structure (cloud) of oscillating standing waves which overlaps the other electron. These oscillating standing waves distort the universal field surrounding a distant electron. After additional previously described steps, this causes the distant electron to experience unbalanced pressure which we consider gravitational attraction.

This description raises the question: *How big is an electron? If we include an electron's standing wave cloud, an electron's radius is as big as its gravitational influence.* By this definition, an electron that formed shortly after the Big Bang has an extended radius, which theoretically equals the distance to the particle horizon of the universe.

14. Wave-particle duality

A fundamental mystery of quantum mechanics can be illustrated by the following example. A propagating electron prior to being observed does not appear to have a specific location. It can only be described by a diffuse wave function distributed over a volume. However, when an electron collides with an object such as a detector screen, it has been "observed." According to the Copenhagen interpretation, the interaction with another object causes the superposition of multiple eigenstates to collapse to a single eigenstate.

A propagating electron is often visualized as a point particle that discontinuously jumps from point to point. The distribution of these jump points creates a "wave of probability." In the point particle interpretation, the particle property is dominant because the wave properties are created by the distribution of the discontinuous jumps of the fundamental point particle.

The model of an electron presented here has the opposite emphasis. In this model, an electron is fundamentally a rotating wave with amplitude of Planck length. The electron's particle-like properties are created by the wave having $\hbar/2$ quantized angular momentum. When an electron (a distributed quantized wave) interacts with another object, there must be a super-luminal adjustment (collapse) of the distributed quantized wave because all the quantized angular momentum must collapse to a much smaller wave distribution of an electron bound to a detector surface.

The universal field makes it possible to have an alternative model of the universe dominated by real waves (not waves of probability). Some problems and concepts are better addressed using a model where waves are dominant rather than point particles.

15. What is electrical charge?

One of the most fundamental mysteries of physics is: What is electrical charge? Does electrical charge have a conceptually understandable physical structure? The mystery of electrostatic force being independent of fermion energy is currently "explained" by merely declaring different energy fermions such as electrons and muons have a property called "electrical charge," which is independent of fermion energy. However, this disconnect between electrostatic force and fermion energy makes "electrical charge" appear to be a fundamental property of nature without a conceptually understandable physical explanation. We think of gravity as a great mystery, but at least we can see that gravitational effects scale with mass (energy). With electrical charge, we do not even have that level of understanding.

Therefore, a severe test of the universal field model of the universe is to see if the model can *conceptually explain* how a muon can have 207 times more energy than an electron but generate the same electrostatic force (have the same charge) as an electron. This question was addressed superficially in the text discussing Eq. (32). It showed a mathematical cancelation, but the underlying physics was not explained.

The deeper answer to this mystery starts with the understanding that an electron and a muon both have a wave with Planck length displacement amplitude in their cores. These two rotating waves have a different frequency (ω_c), different energy, a different Compton radius (r_c) and a different core strain amplitude (L_p/r_c). However, electrons and muons not only have the same displacement wave amplitude in their cores, but they also have the same vacuum polarization effect at the edge of their cores. Therefore, the standing waves external to the core have the same first order strain amplitude ($A_r = \alpha^{1/2}L_p/r$) even though they have very different frequencies. *Electrical potential scales with first order strain amplitude, not wave frequency (energy). Therefore, electrons and muons have the same charge while having different energies.*

The working hypothesis is that the first order standing waves produce a non-oscillating distortion in the surrounding universal field that scale with amplitude $\alpha^{1/2}L_p/r$, not with energy. The slope to this non-oscillating distortion is also $\alpha^{1/2}L_p/r$. This non-oscillating distortion is the electric field we can measure. The difference between positive and negative charge is opposite slope directions, but the fundamental difference is currently unknown.

This quantized wave model also predicts that both an electron and a muon should have the same percentage of their annihilation energy ($E = mc^2$ energy) in their electric/magnetic field. This means the muon's electric/magnetic field must have 207 times more total energy external to its Compton radius than an electron. This is possible because a muon's Compton radius (mathematical radius) is 207 times smaller than an electron's Compton radius. All this additional electric/magnetic field energy is contained in the small spherical shell volume with inner radius equal to a muon's Compton radius (1.86×10^{-15} m) and outer radius equal to an electron's Compton radius (3.86×10^{-13} m). An electron and a muon both have the same energy in their electric fields beyond the distance of 3.86×10^{-13} m. Since we only measure electrical charge at a distance larger than 3.86×10^{-13} m, it appears to us that there is no difference between the electric field of a muon and an electron.

16. Charge conversion constant

The electron model creates an oscillation amplitude in the standing wave cloud of $\alpha^{-1/2}A_r = \alpha^{-1/2}L_p/r$. However, this appears to also create a non-oscillating distortion (slope) in the universal field that is only partly understood. Here we attempt to quantify this partially understood effect.

Equation (22) quantifies the magnitude of the dimensionless electrical potential generated by a hypothetical fermion with Planck charge as $\mathcal{V}_E/\mathcal{V}_p = L_p/r$. Note that L_p/r defines the electrical potential of Planck charge in natural units without the need to incorporate a time component. Also, the dimensionless electric field produced by Planck charge is $\mathcal{E}_E/\mathcal{E}_p = L_p^2/r^2$. Again, Planck length appears in this equation but not a time term.

One physical interpretation of $\mathcal{V}_E/\mathcal{V}_p = L_p/r$ and $\mathcal{E}_E/\mathcal{E}_p = L_p^2/r^2$ is that Planck charge ($\pm Q_p$) produces a $\pm$ Planck length ($\pm L_p$) non-oscillating spatial distortion of the universal field. The dimensionless ratio L_p/r appears to be a polarized spatial slope produced by Planck charge at distance $r \geq r_c$. A unit of length, such as a meter, is omnidirectional. However, the non-oscillating distortion produced by Planck charge is clearly radially polarized. Without attempting further physical interpretation, we will quantify and test this concept.

$$\frac{Q_p}{L_p} = \sqrt{\frac{4\pi\varepsilon_o c^4}{G}} = 1.16\times10^{17} \text{ C/m} \qquad (43)$$

Equation (43) shows the "charge conversion constant" Q_p/L_p with units of coulombs per meter (C/m). This proposed constant replaces the unit of "coulomb" in electrical constants (ε_o, μ_o, Z_o, e) with a polarized distortion of the spacetime field with units of length. Charge e produces a proportionally smaller, non-oscillating distortion of $\alpha^{1/2}L_p \approx 1.4\text{x}10^{-36}$ m. This results in a slope of $\alpha^{1/2}L_p/r$ at distance r from the center of an electron. In the author's previous articles [45, 46], this charge conversion constant is designated η, but Q_p/L_p is more intuitive.

The geometrized unit system, sometimes used with GR, sets $G = c = \varepsilon_o = 1$. This assumption also converts charge to units of length. However, the geometrized unit system merely adopts the convention of $\varepsilon_o = 1$ for mathematical simplification. The charge conversion constant is based on a model in which electrical charge produces a non-reciprocal physical distortion of length in the universal field.

$$\left(\frac{Q_p}{L_p}\right)^2\left(\frac{1}{4\pi\varepsilon_o}\right) = \left(\frac{4\pi\varepsilon_o c^4}{G}\right)\left(\frac{1}{4\pi\varepsilon_o}\right) = \frac{c^4}{G} = F_p \qquad (44)$$

$$\left(\frac{Q_p}{L_p}\right)^2 Z_o = \left(\frac{4\pi\varepsilon_o c^4}{G}\right)\left(\frac{1}{\varepsilon_o c}\right) = 4\pi\frac{c^3}{G} = 4\pi Z_s \text{ kg/s} \qquad (45)$$

We can test this charge conversion constant to provide a new physical interpretation of electrical constants. The Coulomb force constant $1/4\pi\varepsilon_o$ has units of $\text{kg·m}^3/\text{s}^2\text{C}^2$. To cancel the coulomb squared units, this needs to be multiplied by $(Q_p/L_p)^2$. As shown in Eq. (44), this converts the Coulomb force constant ($1/4\pi\varepsilon_o$) to Planck force ($F_p = c^4/G$) with units (kg·m/s^2). This is both surprising and reasonable because Planck force is the force standard in natural units ($F_p/F_p = 1$). Therefore, this conversion predicts that the Coulomb force constant $1/4\pi\varepsilon_o$ is merely another way of stating this universal maximum force standard. The conversion of $\mu_o/4\pi$ is c^2/G.

However, most revealing is Eq. (45), which eliminates units of coulomb (C) from the impedance of free space $Z_o = 1/\varepsilon_o c = 376.7\ \text{m}^2\text{kg/C}^2\text{s} = 376.7\ \Omega$. This is the impedance encountered by EM radiation. This conversion says the impedance encountered by EM waves (Z_o) is virtually the same as the impedance encountered by GWs: $Z_o \Rightarrow 4\pi Z_S$ with units of kg/s. Planck impedance $Z_p = 1/4\pi\varepsilon_o c = 29.98\ \Omega$ converts exactly to the strain impedance of spacetime $Z_p \Rightarrow Z_S$.

Therefore, EM radiation encounters the same impedance (c^3/G) as GWs. This is also the same impedance derived in Eq. (5) from the quantum vacuum. Therefore, photons must be quantized waves propagating in the universal field.

If the universal field propagates light, there are similarities to the classical aether. However, the difference is that the universal field also forms fundamental fermions and fundamental forces. Therefore, everything (rulers, clocks, energy, forces, etc.) scales with this single field. It achieves Lorentz invariance, which explains why it is not possible to detect motion relative to this medium. The Michelson Morley experiment achieved a null result because both the wave-based interferometer and the light experienced the same scale change. *The flaw in the classical aether model was the aether's only function was to propagated light. It did not go far enough and generate everything in the universe.*

From 1916 until his death in 1955, Einstein believed in a variation of the aether, which gave physical properties to space and achieved relativistic properties. He had various names for this concept, including "physical space" and the "relativistic ether" [20]. Einstein also anticipated that matter is derived from the "physical states of space." In 1930 Einstein said,

"Now it appears that space will have to be regarded as the primary thing and that matter is derived from it, as a secondary result." [47].

The universal field model achieves both of Einstein's concepts. In this model, the quantum vacuum (physical space) generates matter. Also, motion relative to the universal field cannot be measured because it achieves Einstein's concept of being a "relativistic ether." While most contemporary physicists were considering particles as fundamental, Einstein was considering particles as a "secondary result" derived from physical space.

17. Photons and Compton scattering

References [45, 46] go into more detail about the photon model. *These references determine that all individual photons have the same displacement amplitude (Planck length, L_p) in "maximum confinement". This explains why the equation for photon energy $E = \hbar\omega$ does not require an amplitude term.* Normally the energy of a wave depends on wave amplitude, but all photons and all fundamental fermions have the same fundamental amplitude (L_p). Therefore, it is possible to write an equation for the energy of a photon ($E = \hbar\omega$) without having to specify a variable amplitude term.

Compton scattering is often cited as conclusive proof that photons are corpuscular particles. However, [45] reexamines this and shows that a quantized wave explanation of Compton scattering is not only plausible, but it is proposed to be better than the particle-based explanation. The reason is that the quantized wave electron can transition from the before scattering wave structure to the after scattering wave structure without transiting trough (accelerating through) forbidden intermediate velocities. Also, *the same wave reflection mechanism, which creates the inward propagating component of an electron's standing waves, also causes the reflections in the wave-based explanation of Compton scattering.* This is partially explained in reference [45].

There is no maximum volume for a quantized wave photon. The length of the quantized waves that form a photon is the inverse of its bandwidth times the speed of light. For example, there are stable lasers with a bandwidth of 1 Hz. Therefore, the length of a photon (quantized wave) from this laser is about 3×10^8 m.

The width of the quantized wave photon equals its spatial coherence width. For example, diverging a laser beam so that it retains a spherical wavefront preserves its spatial coherence. Even if a single photon is distributed over a volume of many cubic kilometers (~ coherence length x coherence width^2), it still has a single quantized angular momentum. When it is absorbed, the quantized angular momentum causes a super luminal collapse. All the photon's angular momentum and energy is transferred to a single atom or molecule.

Reference [46] makes the argument that there should be a "strong" and "weak" definition of quantization. Energy would be classified as "weak" quantization. Even though energy is sometimes transferred as a unit and appears to be quantized, *energy is not fundamentally quantized. Energy does not come in discrete quantized units.* For example, suppose a photon's energy only came in integer multiples of 0.1 eV. Then it would meet the definition of being classified as "strong" quantization. Instead, photon energy smoothly changes with the observation frame of reference. There is no minimum photon energy.

Only angular momentum is fundamentally quantized. The exchange of angular momentum only comes in integer multiples of ħ. Fermions also possess ħ/2 quantized angular momentum. Even if a photon is observed from an arbitrary frame of reference, its angular momentum is always ħ or in rare cases an integer multiple of ħ. An electron always has ħ/2 quantized angular momentum, even when it has large kinetic energy. This is strong quantization. *A quantized unit of angular momentum is the "excitation" required to create a photon or fermion from the universal field. Quantized angular momentum gives the particle-like properties to waves in the universal field.*

If a photon encounters a double slit, the photon's quantized angular momentum demands that either 100% or 0% of the quantized angular momentum pass through both slits. This is similar to an electron encountering a double slit. If the photon's angular momentum passes through both slits, the quantized waves reform beyond the slits with the distribution characteristic of the double-slit interference pattern. After traversing the distance to the target, the distributed wave with quantized angular momentum then strikes all areas of the target within the diffraction pattern. However, rather than having the energy broadly distributed, the ħ quantized angular momentum can only be deposited in one atom or molecule. The quantized wave collapses to this small size and deposits its quantized ħ angular momentum. The photon's entire energy is also deposited into this small volume as a byproduct of the transfer of quantized angular momentum.

For another example, suppose a photon passes through a circular aperture and acquires the diffraction pattern characteristic of the aperture. Then far from the aperture there is a relatively small mirror. There is a probability the photon will be 1) reflected by the mirror, 2) be absorbed by the mirror or 3) will miss the mirror. In the quantized wave model, the photon's distributed quantized waves encounter both the mirror and the surrounding space. The quantized wave must "decide" whether 1) to collapse to the size of the mirror and be reflected with a new wave function but retain all the quantized angular momentum, 2) bypass the mirror with a wave diffraction pattern missing the mirror area but retaining all ħ quantized angular momentum or 3) collapse and deposit all the quantized angular momentum and energy absorbed into an atom on the mirror's surface.

The previous description should not imply that the transfer of the photon's angular momentum and energy to an atom happens in an instantaneous quantum jump. Experiments have shown that the emission or absorption of a photon takes time [48]. The emission time corresponds to the inverse of the photon's bandwidth. For example, a photon from a stable laser with a 1 Hz bandwidth takes 1 second to be emitted. Absorption also takes time determined by the absorption bandwidth. The collapse of the photon's distributed waves can happen faster than the speed of light, but the absorbing object can also determine the time required for absorption.

18. Gravity revisited

18.1 Alternative derivation of gravitation

The yellow lobe in an electron's core in Fig 6 produces a distortion of the universal field, which increases the spatial distance between points and decreases the rate of time. At the center of the yellow lobe, the gravitational time dilation $d\tau$ is $(dt/d\tau - 1) = Gm_p/c^2r_c = 4.18\text{x}10^{-23} = L_p/r_c$. The rate of time at this point equals the rate of time at distance $r_c = 4.18\text{x}10^{-13}$ m from a hypothetical Planck mass (m_p).

The center of the blue lobe has the same rate of time magnitude, but the opposite polarity. The rate of time in the blue lobe is increased relative to coordinate time. The maximum rate of time gradient is the center of the Fig 6, halfway between the two lobes. This is a black area because Fig 6 depicts spatial distortion, not temporal distortion. The center of Fig 6 has no spatial distortion and maximum temporal distortion. The rotating rate of time gradient at the center of the electron model has maximum energy density.

However, how does this model produce a cumulative net loss of time external to the core? Merely oscillating the rate of time should produce canceling effects. The key to the electron's time dilation is that the two lobes are not precisely the same size. The yellow lobe is about L_p bigger than Euclidian geometry predicts, and the blue lobe is about L_p smaller than expected from geometry. This means as they rotate, the influence of the yellow lobe lasts slightly longer than the blue lobe's influence. They almost cancel, but for an electron, *each radian of rotation* averages to $(L_p/\lambda\!\!\!^{-}_c)T_p/\mathcal{N} = 2.25\text{x}10^{-66}/\mathcal{N}$ seconds lost at a distance measured in dimensionless $\mathcal{N}$. To obtain the time lost per second, we need to multiply by ω_c. Therefore, $(L_p/\lambda\!\!\!^{-}_c)T_p\omega_c/\mathcal{N} = (L_p/\lambda\!\!\!^{-}_c)^2/\mathcal{N} = \mathcal{N}A_r^2$ seconds/second at distance $\mathcal{N} = r/\lambda\!\!\!^{-}_c$. This generates Eq. (29) which is $dt/d\tau = 1 + \mathcal{N}A_r^2$.

This explanation can also focus on a temporal derivation. A hypothetical point clock at distance $\mathcal{N}$ from an electron's center of mass would record *equal proper time* spent in both the blue and yellow rotating standing waves in Fig 10. However, a distant coordinate clock would record slightly more time spent under the influence of the slow time yellow lobe. Again, this results in the point clock having a cumulative time loss of $dt/d\tau = (L_p/\lambda\!\!\!^{-}_c)^2/\mathcal{N} = 1.75\text{x}10^{-45}/\mathcal{N}$ seconds/second.

18.2 Gravitational effect on time and energy

The previous discussion about the quantized wave model of gravity was incomplete. However, a complete explanation requires that we first start by developing equations related to the local gravitational distortion of the universal field enveloping an electron. Usually, gravitational equations incorporate mass and distance. These work well to give mathematical results, but they do not explain the underlying physical mechanism which generates a force when an electron in a gravitational field is prevented from following the geodesic. We are left with mysterious action at a distance.

The quantized wave model gives a conceptually understandable answer, but it involves several steps which start with the gravitational rate of the time gradient. It is well known that light propagating vertically in a gravitational field undergoes what appears to be a gravitational redshift. This apparent redshift is not the result of gravity removing energy from the photons. Instead, the gravitational effect on the rate of time makes it appear that the photon's frequency (υ) and energy decreases when measured locally at increasing elevation. [49]. The following example will illustrate this. Suppose light with frequency υ_o is emitted vertically in a gravitational field with acceleration g. The emission point is designated level 0. The light propagates a vertical distance $\mathcal{H}$ from level 0 to a higher-level designated level 1. At this higher level, the frequency appears to be υ_1 when measured using a local clock. The rate of time is designated $d\tau_0$ and $d\tau_1$ for levels 0 and 1, respectively.

$$\frac{\upsilon_1}{\upsilon_0} = \left(1 - \frac{g\mathcal{H}}{c^2}\right) \tag{46}$$

Desloge [50] has derived an exact equation that connects the gravitational effect on a photon's frequency to gravitational acceleration (g). This is Eq. (46). To obtain this exact solution, υ_0, g and $\mathcal{H}$ must be measured at level 0, and υ_1, must be measured at level 1. Also, the distance $\mathcal{H}$ must be the "radar length" distance measured from level 0 to level 1. Finally, this equation assumes uniform gravitational acceleration. Therefore, the assumption is that distance $\mathcal{H}$ is small enough that the gravitational acceleration (g) can be considered constant over distance $\mathcal{H}$.

If photon frequency could be measured using a single time standard ("coordinate time"), then it would be found there is no change in frequency at the two elevations. For example, a clock at level 0 can be designated the coordinate clock with the rate of time $d\tau_0$. The apparent difference in photon frequency (υ_0 vs. υ_1) is due to the different rates of time at elevations 0 and 1 (different local clocks). The relationship is $\upsilon_1/\upsilon_0 = d\tau_0/d\tau_1$.

$$\frac{d\tau_1 - d\tau_0}{d\tau_1} = \frac{g\mathcal{H}}{c^2} \tag{47}$$

This generates Eq. (47), which gives the relationship between the rate of time gradient between these two levels and gravitational acceleration (g). For example, a locally measured gravitational acceleration of 1 m/s^2 corresponds to a rate of time gradient of about 1.113×10^{-17} seconds/second/meter. Therefore, the gravitational acceleration at the earth's surface (9.8 m/s^2) corresponds to a rate of time gradient of about 10^{-16} s/s·m. For comparison, currently, the most accurate quantum-logic clocks reference a single aluminum ion to achieve an accuracy of about 10^{-18} [51]. This approximately equals the difference in the rate of time over an elevation change of 1 cm in the earth's gravitational acceleration.

It is not easy to fully appreciate the far-reaching effects caused by a change in the rate of time. When the rate of time is different between two locations, but the laws of physics are the same, many coordinated physical changes are required. This is not a simple analogy to speeding up or slowing down a video. For example, momentum and electric current scale proportional to $1/t$, energy, and force scale proportional to $1/t^2$, power scales proportional to $1/t^3$, while the length and the fine structure constant are independent of time $1/t^0$. This is time raised to four different powers, yet the laws of physics are constant even with this difference in time dependence.

$$\frac{d\tau_0}{d\tau_1} = \frac{E_0}{E_1} = \frac{F_0}{F_1} = \frac{\mathcal{P}_0}{\mathcal{P}_1} = \left(1 - \frac{g\mathcal{H}}{c^2}\right) \tag{48}$$

Equation (48) shows a few of the many additional changes required to preserve the laws of physics. This equation designates units of energy (E_0), force (F_0), and pressure ($\mathcal{P}_0$) at level 0. Perhaps the most apparent change in addition to the rate of time is the change in the energy standard. The photon emitted at level 0 appears to have a lower frequency and lower energy (redshift) when it reaches level 1. However, if we apply the level 0 rate of time and energy standard (coordinate time and energy standard), there is no change. One joule at level 1 is a larger unit of energy on an absolute scale than 1 joule at level 0. Equation (48) expresses this concept as ($E_0/E_1 = 1 - g\mathcal{H}/c^2$). In the Earth's gravity ($g \approx 9.8$ m/s^2), a 1 meter elevation difference ($\mathcal{H} = 1$ m) causes 1 joule at level 1 to exceed 1 joule at level 0 by about 1 part in 10^{16}. The gravitational effect on energy is the basis for the following discussion on gravitational potential energy.

18.3 Gravitational potential energy

Where exactly is gravitational potential energy stored? If we lift an electron with mass m_e a vertical distance $\mathcal{H}$ in a gravitational field with acceleration g, we say we have given the electron gravitational potential energy of $E_g = mg\mathcal{H}$. *Elevating an electron not only changes its gravitational potential energy but also increases its gravitational mass (absolute value). However, the elevation does not change an electron's electrical charge.* Is it possible for this quantized wave model to explain all three of these effects?

The quantized wave model of an electron is a wave in a universal field rotating at its Compton frequency $\upsilon_c \approx 1.236\times10^{20}$ Hz. This frequency assumes we use a local clock to time the rotation frequency. When we elevate an electron from level 0 to level 1, we are doing physical work (adding energy). This work increases the rotational frequency by the exact amount required to keep the same frequency when measured by the faster level 1 clock. This is not a coincidence. Suppose we could accurately count the electron's rotation rate. Then an electron could be the frequency standard of a very accurate clock. Elevating an electron from sea level (level 0) to 1 meter above sea level (level 1) in the earth's gravitational field ($g \approx 9.8$ m/s^2) would increase the electron's rotation rate by $\upsilon_1 - \upsilon_0 = \upsilon_1 g\mathcal{H}/c^2 \approx 13{,}470$ Hz. This increase is only observable if the rotation rate is compared to the rotation of an electron at level 0. However, if the rotation rate is timed using an accurate clock at level 1, there would be no change in rotation rate.

There is no gravitational change in the value of Planck's constant, so the faster rotation rate means that the electron has more energy (absolute scale) on level 1 than it had on level 0. The difference in energy is $E_1 - E_0 = 13{,}470$ Hz x $h \approx 8.93 \times 10^{-30}$ J. This is precisely the potential energy gained by elevating an electron ($m_e = 9.1 \times 10^{-31}$ kg) a distance of $\mathcal{H}$ = 1 meter in a gravitational acceleration of $g = 9.8$ m/s^2.

$$E_1 - E_o = E_1 \frac{g\mathcal{H}}{c^2} = m_1 g\mathcal{H} \tag{49}$$

The equation for the difference in energy between level 0 energy (E_0) and level 1 energy (E_1) is Eq. (49). This equation converts Eq. (48) to the equation for gravitational potential energy $E_1 - E_0 = m_1 g\mathcal{H}$. *An electron's gravitational potential energy is stored as a physical change in the absolute value of the core's rotational rate.*

The second of the three proposed questions is: Why does an electron's gravitational mass change with gravitational potential? An electron at level 1 produces a slightly stronger gravitational field (gravitational curvature) than an electron at level 0. This has nothing to do with a difference in radial distance. The electron at level 1 has a higher frequency (absolute value) than an electron at level 0. This higher frequency affects the standing waves produced external to an electron's Compton radius. As previously described in Eq. (29), the gravitational time dilation produced by an electron is $dt/d\tau = 1 + \mathcal{N}A_r^2 = 1 + L_p^2\omega_c/cr$. The fact that $dt/d\tau$ scales with ω_c means that when an electron has a change in elevation (gravitational potential), there is a change in the gravitational mass, gravitational curvature, and gravitational force produced by the electron.

The last of three questions is: Why does a change in elevation (gravitational potential) produce no change in an electron's electrical charge e? From Eq. (21), an electron's dimensionless electrical potential is $\mathcal{V}_E/\mathcal{V}_p = (\alpha)^{1/2}L_p/r$. Note that this electrical potential is independent of ω_c. Why is this?

When there is an increase in elevation, there is an increase in ω_c. There is also a decrease in the electron's Compton radius. The increase in ω_c does produce an increase in the energy in the electric field of the elevated electron. However, all the increased electric field energy is used to fill the additional volume between the level 1 and level 0 Compton radii. Therefore, there is no difference in the electric field (charge) measured far beyond the electron's Compton radius.

Therefore, the quantized wave model explains 1) gravitational potential energy storage, 2) the change in gravitational mass when gravitational potential energy changes, and 3) the lack of any change in electrical charge when there is a change in gravitational potential.

18.4 Gravitational force

Equation (30) $F_G/F_p = (\mathcal{N}A_r^2)^2$ generated the correct dimensionless force magnitude between two of the same mass fermions, but this is an oversimplification. This oversimplified calculation assumed a first electron was continuously emitting traveling waves with an electron's Compton frequency and strain amplitude of $(L_p/r_c)^2$. A second electron with core area kr_c^2 absorbs the portion of this emission that strikes the surface area. This calculation generates the correct force magnitude, but this would be a repulsive force.

To obtain the correct force vector and eliminate the need for the continuous loss of energy by wave emission, the analysis needs to include the electron's physical structure. In particular, we need to address an electron's internal pressure. The units of energy density (U) and pressure ($\mathcal{P}$) are equivalent: J/m^3 = N/m^2 = kg/s^{2}m. A collimated beam of light with energy density U striking an absorbing surface has the relationship $U = \mathcal{P}$. This relationship is $U = 3\mathcal{P}/2$ if EM radiation is confined in a box with 100% reflecting walls. This analysis uses approximations, so we are ignoring the numerical constant near 1 and using $U = \mathcal{P}$.

The energy density of the electron model is about $U = E_i/r_c^3 = 1.42 \times 10^{24}$ J/m^3. Therefore, the electron's internal pressure is about 1.42×10^{24} N/m^2. For an isolated electron to be stabilized, it requires two steps. First, at the edge of the core there has to be a reduction in first order wave amplitude from L_p to $\alpha^{1/2} L_p \approx 0.085L_p$. This was previously described as "vacuum polarization". It only affects the first order waves, not the second order waves responsible for an electron's gravity. The second form of stabilization is the previously discussed resonant reflections in the surrounding universal field. These reflections form both first order and second order standing waves. These returning waves eliminate energy loss and exert an offsetting pressure on all sides of the electron's rotating core. The following explanation only addresses gravity.

What happens if an electron is being held at a constant elevation in a gravitational field? To explain this problem and the solution, it is easiest if we imagine an isolated electron as a cube with dimensions equal to an electron's Compton radius $\lambda\!\!\!^{-} = 3.86 \times 10^{-13}$ m. This cube has internal pressure equal to an electron's core pressure of 1.42×10^{24} N/m^2. Each surface of this cube has area r_c^2. Therefore, the force on each surface is $F_m = \hbar c/r_c^2 =$

0.212 N. If this hypothetical cube is in a gravitational field with the rate of time gradient specified in Eq. (47), then the top surface of the cube encounters a different rate of time compared to the bottom surface. In Eq. (48), we previously calculated the difference in the units of energy between levels 0 and 1. Equation (48) states that there is a similar effect on the unit of force $F_0/F_1 = (1 - g\,\mathcal{H}/c^2)$. This claim can be proven, but the proof requires a diversion from the subject matter of this article. Adopting $F_0/F_1 = (1 - g\mathcal{H}/c^2)$ will also be supported if it generates reasonable answers.

The top and bottom surfaces of the hypothetical electron cube in gravity both are receiving a force of 0.212 N (measured locally). But on an absolute scale there is a slight difference in both the frequency and the force exerted the top surface compared to the bottom surface of the hypothetical cube. The upper surface is receiving a larger force than the lower surface due to the rate of time gradient. The force difference ($F_1 - F_0 = \Delta F$) between the top and bottom surface is calculated using an equation similar to Eq. (49). $F_1 - F_0 = F_1(g\mathcal{H}/c^2)$. We will also set $F_1 = \hbar c/r_c^2 = m^2c^3/\hbar = 0.212$ N and $\mathcal{H} = r_c = \hbar/mc$.

$$F_1 - F_0 = F_1 \frac{g\mathcal{H}}{c^2} = \frac{m^2c^3}{\hbar} g \frac{\hbar}{mc} \frac{1}{c^2} = mg \qquad (50)$$

The net force ($\Delta F = mg$) in Eq. (50) gives the correct gravitational force on mass m in a gravitational field with acceleration g. The external pressure (repulsive force) on the top surface of the cube is larger than the pressure (repulsive force) on the bottom surface of the cube. Therefore, the force vector is correct. The net gravitational force appears to be attraction, but it is actually the difference between two opposing repulsive forces (pressures). The previous analysis used the simplification of a cube rather than a sphere. In a plausibility calculation, we are dealing with approximations and can ignore this difference, which is a numerical constant near 1.

19. Single fundamental force

This article has discussed the gravitational force and electromagnetic force. These forces appear to be distinct, but these forces have been shown to be related in the tests of the electron model. The other two forces are also related but not discussed in detail here. *The quantized wave model of the universe has only one fundamental force, and it is always repulsive.* Quantized waves in the universal field (waves with quantized angular momentum) have observable energy and momentum (p). When these waves interact, there is a transfer of momentum. *The rate of change of momentum is the only force transferred by quantized waves: $\mathbf{F} = d\mathbf{p}/dt$. It is always repulsive.*

The most familiar example of this repulsive force is the radiation pressure exerted when light is emitted or absorbed ($F = P/c$), where P is power. For example, a laser beam with a power of 3×10^8 watts exerts 1 N repulsive force when it is absorbed or 2 N if this beam is reflected by a perpendicular mirror.

Gravity and opposite polarity electrostatic force appear to be forces of attraction. However, these are obtained from unbalanced pressure, which is a repulsive force applied over an area. It is not apparent that these forces originate from wave interactions distorting the universal field. The insight into the single fundamental force led to Eq. (24, 25, 30 – 32).

The strong force can also be derived from repulsive momentum pressure. However, this is a lengthy explanation that is beyond the scope of this article. In this model, the strong force is also connected to the electrostatic force and the gravitational force. The weak force is more complicated because it is transferred by the exchange of W and Z bosons. This still involves the single force, but the addition of an exchange particle adds complexity.

20. Physical laws

The goal of physics has been to generate equations that mathematically describe the physical laws. However, a deeper level of understanding requires that we also understand the source of these laws. What generates the physical laws? These laws are not externally imposed by an unknown source. The proposal is that the properties of a single quantifiable universal field generate everything in the universe, including the physical laws.

Suppose we imagine a remote volume of space far from any galaxy. In that volume, the physical laws are still present. That remote volume still has a universal speed limit (c), a quantization of angular momentum ($\hbar$), a gravitational constant (G), and the impedance of spacetime. Rather than regarding the source of these constants as unknowable, the universal field is physically present in this remote volume. The universal field with fluctuation amplitude $L_p = (\hbar G/c^3)^{1/2}$ and frequency $\omega_p = (c^5/\hbar G)^{1/2}$ generates constants $\hbar$, c and G everywhere in the quantum vacuum.

The potential of this concept will be demonstrated with some examples. First, why is the speed of light a universal speed limit? When sound is transmitted through a gas, the speed of sound is a function of the thermal speed of the atoms or molecules. The universal field is Planck length L_p vacuum fluctuations at Planck frequency ω_p. These fluctuations are all happening at the speed of light because $L_p\omega_p = c$. Therefore, waves in this medium would also propagate at this fluctuation speed (the speed of light). However, this is an oversimplification. Everything scales with this medium (clocks, rulers, electrons, etc.) Several additional steps are required to achieve a constant speed of light for all frames of reference.

An electron can appear to be at rest, but internally there is a wave rotating at the speed of light. This is a confined wave propagating at the speed of light. It exhibits the special relativity properties such as relativistic length contraction in a moving frame of reference $\lambda_x = \lambda_o/\gamma$ Eq. (16). A moving electron also exhibits a relativistic increase in energy ($E_{rel} = \gamma E_o$) because its internal rotating wave has the net Doppler shift properties of counter propagating waves. Both the speed of light limitation and the relativistic increase in energy are examples of the universal field generating familiar laws of physics.

This type of analysis can also give an insight into the gravitational constant, G. What physically generates the gravitational constant? If the universal field is assumed, then there is an answer from Eq. (9). This equation is $\rho_q = k\omega^2/G$, where ρ_q is the quasi-density of the universal field encountered by a wave with frequency ω.

For a GW, $k = 1/16\pi$, but a wave in the universal field that forms a fundamental fermion appears to have $k = 1$. Rearranging terms, this equation gives an insight into the gravitational constant: $G = \omega_c^2/\rho_q$. The gravitational constant (G) has units of $s^{-2}/(kg\cdot m^{-3})$. These units are written this unusual way to emphasize the fact that the gravitational constant has units of frequency squared (s^{-2}) divided by quasi-density ($kg\cdot m^{-3}$): ω_c^2/ρ_q. The physical interpretation is that G is a statement of the quasi-density of the universal field encountered by a wave in the universal field with frequency ω.

These are examples of relatively simple insights into c, G and special relativity. Numerous more challenging problems remain. The quantized wave model is well suited to generate alternative answers to challenging physics problems.

21. Philosophical insights

All mathematical analysis of physics requires the adoption of a set of starting assumptions. These starting assumptions are usually not enumerated, but they are implied by relying on work that previously adopted these assumptions. If one of the starting assumptions is wrong, the mathematical analysis generates mathematically correct but physically incorrect answers. However, *suppose the analysis is using correct assumptions but is missing one or more essential starting assumptions. Then the mathematical analysis gives correct answers, but the missing assumptions leave gaps. These gaps cause the physical interpretation of the calculated answers to contain conceptual mysteries. This is exactly what we have today.*

Physics has numerous mysteries that are not just unknowns at the limit of our current knowledge. Well known mysteries of quantum mechanics and relativity defy logical understanding. The reason for these types of mysteries is proposed to be an incomplete model of the universe caused by missing starting assumptions. Further mathematical analysis of a model with missing essential assumptions is limited by the starting assumptions. New physical insights are required to generate additional assumptions. This article has examined the implications of adding the following assumptions 1) Planck length vacuum fluctuations create a quantifiable universal field that generates everything in the universe and 2) particles are fundamentally quantized waves in the universal field. These assumptions have been shown to generate many useful new insights.

22. Summary and conclusion

This article expands on the model of the quantum vacuum first proposed by John Wheeler in 1955. He proposed that on the Planck scale, the quantum vacuum is undergoing violent Planck length vacuum fluctuations. These fluctuations also produce vacuum ZPE which implies Planck frequency. This article adopts Wheeler's assumptions but adds the following two assumptions: 1) Vacuum fluctuations make the quantum vacuum a stiff elastic medium that propagates waves at the speed of light. 2) This medium is the single universal field which generates everything in the universe. Based on these assumptions, the quantum vacuum is treated like an acoustic medium and found to have impedance which can be stated as either $Z_D = c\omega^2/G$ or $Z_S = c^3/G$.

To test the concept that the quantum vacuum is a universal field, an attempt is made to generate an electron from this medium. For example, a wave with an electron's Compton frequency ($\omega_c = 7.7\times10^{20}$ rad/s) encounters impedance of about 10^{60} kg/m^{2}s. This is so enormous, a wave rotating at the speed of light with this frequency and $\hbar/2$ quantized angular momentum, only needs undetectable amplitude of Planck length (L_p) to achieve an electron's energy and other properties of an electron. This rotating wave forms an electron's core. The Planck length amplitude means it has no detectable radius. Furthermore, in an energetic collision, the added energy causes the radius to momentarily decrease. It always appears to be a point particle with wave-particle properties.

The resulting model of an electron has been analyzed. It exhibits an electron's approximate rest mass, energy, angular momentum, and de Broglie waves. However, the physics of the model unexpectantly also implied it should generate standing waves that distort the surrounding universal field. When this distortion was quantified, it corresponded to an electron's gravitational and electric fields. The mechanism this model uses to generate gravitational and electrostatic forces was analyzed. This analysis generated predictions that an electron's gravitational and electrostatic forces should have specific mathematical relationships. These predictions are explained and verified in Section 12.

The quantized wave model has demonstrated its usefulness in several different ways.

- It generates correct predictions.
- It is useful in the quest to unite the forces of nature.
- It is useful in education because it gives a conceptually understandable visualization of quantum mechanical and relativistic effects.

However, the quantized wave model needs to be developed further using the rigorous mathematical analysis of quantum field theory.

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