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Oscillating Spacetime: The Foundation of the Universe

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Abstract

In this article, spacetime is modeled as a quantum mechanical sonic medium consisting of Planck length oscillations at Planck frequency. Planck length-time oscillations give spacetime its physical constants of c, G and $\hbar$. Oscillating spacetime is proposed to be the single universal field that generates and unifies everything in the universe. The 17 fields of quantum field theory are modeled as lower frequency resonances of oscillating spacetime. A model of an electron is proposed to be a rotating soliton wave in this medium. An electron appears to have wave-particle duality even though it is fundamentally a quantized wave. This soliton wave can momentarily be smaller than a proton in a high energy collision or can have a relatively large volume of an atom's orbital wave function. Finding an electron causes it to undergo a superluminal collapse to a smaller wave size. This gives an electron its particle-like properties when detected. The proposed wave-based electron model is tested and shown to have an electron's approximate energy, de Broglie wave properties and undetectable volume. Most important, this electron model is shown to also generate an electron's electrostatic and gravitational forces. The gravitational properties are derived from the nonlinearity of this medium. When an electron's gravitational and electrostatic forces are modeled as distortions of soliton waves, the equations become very simple, and a clear connection emerges between these forces. For example, the gravitational force between two Planck masses equals the electrostatic force between two Planck charges. Both force magnitudes equal $\hbar c/r^2$.

Keywords

Unification of Forces, Electron Model, Cosmological Constant Problem, Foundation of Physics, Aether

1. Introduction

The research described in this article began with the realization that there is a connection between the properties of light confined inside a laser and the physical properties of particles. The light reflecting between the two laser mirrors is forced to have the mirror's frame of reference. This confined light forms standing waves that exhibit 5 properties we associate with fundamental particles. For example, in a moving frame of reference, the bidirectional light inside a laser exhibits a wave property analogous to the de Broglie waves of a moving electron. The standing waves in a moving laser also undergo relativistic length contraction, relativistic time dilation and relativistic energy increase. Finally, the confined light waves have inertia (rest mass). If the laser is accelerated, the light inside the laser exerts unequal pressure on the laser's two mirrors. This produces a net force that resists acceleration. This is the inertia of the light's energy. These 5 effects will be explained in Sections 7 and 8 of this article. These insights prove that when light is confined to a specific frame of reference, the light exhibits particle-like properties.

I am an inventor with many patents related to lasers and optics. Therefore, this surprising insight suggested to me that it might be possible to "invent" a wave-based model of an electron that would incorporate these 5 relativistic and quantum mechanical properties. For example, a rotating soliton wave would be a confined wave with a specific frame of reference. Therefore, a rotating wave model of an electron would acquire these 5 quantum mechanical and relativistic properties.

However, a wave-based electron model would require the existence of a wave propagating medium that went far beyond the aether. Besides propagating light, this sonic medium would have to be the foundation of everything in the universe. The wave propagating medium would need extreme properties, capable of generating all fermions and forces from waves. The standard model has 17 named particles derived from 17 separate fields. Therefore, the vision was that perhaps these 17 overlapping fields could be unified into one wave propagating universal field that generates everything in a wave-based model of the universe. However, this wave propagating medium would require the contradictory properties of having a tremendous energy density capable of supporting the most energetic waves while also appearing to be undetectable to us.

Quantum field theory can be interpreted such that the quantum vacuum is a field consisting of harmonic oscillations with zero-point energy (ZPE) of $\hbar\omega/2$ [1]. If ω equals Planck frequency $\omega = \omega_p = (c^5/\hbar G)^{1/2}$, then the implied energy density of this field equals Planck energy density ($U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3). However, the Wilkinson Microwave Anisotropy Probe observed the universe to be close to the flat Lambda-CDM model [2]. This implies an average energy density of the universe is roughly 10^{-9} J/m^3. Therefore, this 10^{122} discrepancy has been described as "the worst theoretical prediction in the history of physics" [3]. This discrepancy is known as the cosmological constant problem and has been studied extensively [4]. Virtually all the articles written about this subject attempt to explain away the 10^{113} J/m^3. However, if spacetime has an unseen property that mathematically appears to be 10^{113} J/m^3, this could potentially be the wave propagation medium I need to be the foundation of a wave-based model of the universe. Therefore, while others are attempting to explain away this enormous quantum mechanical energy density, I was motivated to prove it actually exists.

Support for the quantum vacuum having a property that mathematically appears to be 10^{113} J/m^3 came from John Archibald Wheeler. He examined the uncertainty principle and vacuum zero-point-energy, then concluded these effects would be explained if the "geometry of spacetime fluctuates" [5] [6]. He concluded that 4-dimensional spacetime consists of Planck length (L_p) vacuum oscillations at Planck frequency (ω_p) [7]. His vision of the quantum vacuum has become the foundation of the model of the universe proposed here. This description of spacetime will be analyzed in Section 4 and shown to have Planck energy density (10^{113} J/m^3) when described mathematically. However, it only becomes observable energy when angular momentum is added (an excitation is added). Introducing a unit of quantized angular momentum into this medium would give a rotating soliton wave a specific frame of reference. We can only detect differences in energy density. Therefore, a rotating wave would be detectable but a homogeneous medium that supports this wave would be more difficult to detect if it is present everywhere.

Wheeler's model of spacetime is commonly designated "quantum foam" or "spacetime foam". However, this article will use the term "oscillating spacetime" because the spacetime model being discussed is literally oscillating. Wheeler presented his concept of spacetime in the last chapter of the authoritative reference he coauthored [7]. This reference states, "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: "The geometry of space is subject to quantum fluctuations in metric coefficients of the order of: Planck length/length extension of the region under study" [7]. There have also been many articles about spacetime foam and related subjects [8]. None of those articles give details suggesting that spacetime foam is the fundamental building block of everything in the universe.

The following article starts with a discussion of the sonic properties of oscillating spacetime consisting of Planck length oscillations at Planck frequency. These properties include the calculation of its propagation speed, impedance and bulk modulus. A wave-based model of an electron is developed from this medium. Tests of this electron model show it achieves an electron's energy, de Broglie waves, and spin. This model unexpectantly is found to also generate an electron's electrostatic and gravitational forces. Treating these forces as wave interactions in oscillating spacetime results in proof that these forces are closely related. The wave-based model of the universe also makes several predictions about gravitational relationships, photons, entanglement, and the Big Bang. The conclusion is that this is a successful and useful model of the universe.

2. Names and Units

This article addresses the big picture of a wave-based model of the universe. Many different subjects will be addressed. 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. These simplifications still convey fundamental concepts without the added burden of specifying numerical constants and vectors. Electrons are use in examples, but these examples also apply to muons or tauons. Discussions of electric fields also imply magnetic properties.

This article proposes that spacetime itself has the properties of a sonic medium that propagates waves at the speed of light. Spacetime will be modeled as John Wheeler's "spacetime foam" (designate oscillating spacetime here) consisting of Planck length oscillations at Planck frequency. The multiple fields of quantum field theory will be modeled as resonances and distortions of this fundamental medium. All fermions will be modeled as soliton rotating waves (sonic quasi-particles). This is explained in Section 5, 7, 8 and **Figures 1-5**.

This article also elevates Planck length beyond its usual definition. The symbol l_p or ℓ_p is usually used to represent Planck length. However, this article uses the symbol L_p to elevate its importance and imply it is the fundamental wave amplitude of oscillating spacetime. This medium has multiple properties that equal 1 when expressed in Planck units. Below is a list of base Planck units that will be used in this article:

Planck length:	$L_p = \left(\hbar G/c^3\right)^{1/2} = 1.62\times10^{-35}$ m ,
Planck time:	$t_p = \left(\hbar G/c^5\right)^{1/2} = 5.39\times10^{-44}$ s ,
Planck mass:	$m_p = \left(\hbar c/G\right)^{1/2} = 2.18\times10^{-8}$ kg ,
Planck frequency:	$\omega_p = \left(c^5/\hbar G\right)^{1/2} = 1.86\times10^{43}$ rad/s ,
Planck force:	$F_p = c^4/G = 1.21\times10^{44}$ N ,
Planck density:	$\rho_p = c^5/\hbar G^2 = 5.16\times10^{96}\ \mathrm{kg/m^3}$,
Planck energy:	$E_p = \left(\hbar c^5/\mathrm{G}\right)^{1/2} = 1.96\times10^{9}$ J ,
Planck energy density:	$U_p = c^7/\hbar G^2 = 4.64\times10^{113}\ \mathrm{J/m^3}$,
Planck pressure:	$\mathcal{P}_p = c^7/\hbar G^2 = 4.64\times10^{113}\ \mathrm{N/m^2}$,
Planck temperature:	$\mathcal{T}_p = m_p c^2/k_B = 1.42\times10^{32}$ K ,
Planck charge:	$q_p = \left(4\pi\varepsilon_0\hbar c\right)^{1/2} = 1.88\times10^{-18}$ C ,
Planck electrical potential:	$\mathcal{V}_p = \left(c^4/4\pi\varepsilon_0 G\right)^{1/2} = 1.043\times10^{27}\ \mathcal{V}$.

Here is a list of the symbols and equations that will be commonly used throughout the manuscript.

$\omega_c = mc^2/\hbar$	Compton angular frequency,
$\lambda\!\!\!^{-} = \lambda/2\pi = c/\omega$	Angular wavelength (Lambda bar),
$\lambda\!\!\!^{-}_c = \hbar/mc$	Compton angular wavelength of a fermion,
$r_c = \lambda\!\!\!^{-}_c = \hbar/mc$	Compton radius of a fermion (3.86×10^{-13} m for electron),

$r_G = L_p^2 r_c = Gm/c^2$ Gravitational radius of a fermion (6.76 × 10^{-58} kg for electron),

r_q Charge radius—For charge *e*, $r_q = \alpha^{1/2} L_p = 1.38 \times 10^{-36}$ m,

$N \equiv r/r_c = rmc/\hbar$ Number of Compton radii between fermions with mass m,

$Z_s \equiv c^3/G = 4 \times 10^{35}$ kg/s Strain impedance of spacetime,

$\gamma = \left(1 - v^2/c^2\right)^{-1/2}$ Lorentz factor,

$\alpha = e^2/4\pi\varepsilon_0 \hbar c \approx 1/137$ Fine structure constant,

$e = \alpha^{1/2} q_p \approx 1.6 \times 10^{-19}$ C Elementary charge *e*,

$F_e \equiv e^2/4\pi\varepsilon_0 r^2$ Electrostatic force between 2 electrons,

$F_{qp} \equiv q_p^2/4\pi\varepsilon_0 r^2$ Electrostatic force between 2 Planck charges,

$F_G \equiv G m_e^2/r^2$ Gravitational force between 2 electrons,

$\mathcal{A}_e \equiv L_p/r_c = 4.18 \times 10^{-23}$ Electron's core strain amplitude (dimensionless).

3. The Lorentz Transformation Test

In the 19th century, the aether was widely assumed to exist. Since light appeared to be waves, it was reasoned that the vacuum of space must contain a wave propagation medium (the aether). However, the aether was abandoned for three reasons. 1) Experiments failed to detect the aether, 2) Photons exhibited particle properties, and 3) Einstein's special relativity theory postulated no privileged reference frame required by the aether. (A sonic medium's "privileged reference frame" is defined as the rest frame of the sonic medium.) Gravitational waves (GWs) are known to propagate through the "fabric of spacetime". It is not necessary to add an aether-like wave propagation medium to spacetime because oscillating spacetime itself has properties that propagate GWs at the speed of light.

This article will treat spacetime as a sonic medium and analyze its properties. The problem is that we do not perceive any wave propagation medium. Fermions move effortlessly through this medium without friction. However, something unseen limits the maximum speed of fermions to the speed of light. The quantum vacuum also has non-zero permittivity (ε_0), permeability (μ_0), and impedance of free space (Z_0). Furthermore, a moving fermion with rest mass/energy E_0 acquires relativistic energy of $E = \gamma E_0$ where $\gamma = (1 - v^2/c^2)^{-1/2}$. This is the well-known Lorentz factor. When Einstein developed special relativity, he made two postulates that were counter intuitive. These postulates led to special relativity and Lorentz transformations. The postulates were:

1) The speed of light in a vacuum is invariant in all inertial frames of reference.

2) All the physical laws are the same in all inertial frames of reference.

It is impossible to logically derive relativistic length contraction, relativistic time dilation, and relativistic energy from the currently accepted model of particles and spacetime. These require at least one of Einstein's postulates. The following example illustrates the problem. Suppose the speed of a bullet is measured by the time it takes the bullet to travel between two detectors. If the detectors are moving relative to the gun, the measured velocity will be the sum of the bullet's velocity relative to the gun and the detector's velocity relative to the gun. This calculation is logical and requires a Galilean transformation. Now suppose this experiment is repeated with a pulse of light. The same speed of light will be obtained, even when the detectors are moving relative to the light source. This result is not logical. It requires a physical change in the distance between the detectors (Lorentz contraction) and a dilation in the rate of time. Calculating this result requires a Lorentz transformation.

Einstein concluded that Maxwell's equations predicted the counter intuitive property of a constant speed of light, independent of the velocity of the observer. Therefore, he made the above two postulates the foundation of special relativity. Einstein's postulates are now such an integral part of physics that we have ignored the fact that our generally accepted model of the universe cannot explain the underlying physics that produces Lorentz transformations.

In 1954, Einstein wrote: "Relativity theory can be summarized in one sentence. All natural laws must be so conditioned that they are covariant with respect to Lorentz transformations" [9] [10]. His two postulates artificially give us length contraction, time dilation and all other relativistic effects. A classical particle moving in an empty vacuum would not acquire relativistic energy $E = \gamma E_0$. A different model of particles and spacetime is required to structurally produce Lorentz transformations. If Einstein had a model of spacetime, particles and forces that logically generated Lorentz transformations, he would not have required postulates to develop special relativity.

Is there any alternative model of the universe that logically generates Lorentz transformations rather than Galilean transformations? The answer is yes. There is a remarkable series of technical articles [10]-[12] that imagine a thought experiment of a hypothetical universe based on sound waves. In this thought experiment, this "sonic universe" is filled with a medium that propagates sound at a sonic speed designated (c_s). These articles *assume everything observable in this hypothetical universe is made of sound waves.* For example, simplified sonic quasi-particles can be visualized as spherical standing sound waves. The point of these articles is not to describe these sonic quasi-particles, but to imagine the physics of a universe based on the foundation of a single universal sound propagating field. Particles would be sonic quasi-particles and forces would be transmitted through this sonic medium. In other words, everything in this hypothetical universe is derived from the sonic medium. All of the properties of special relativity can be derived from a universe based entirely on sound [10]-[12].

The first of these articles is titled "*A Real Lorentz-FitzGerald-Contraction*, [10]". In this article, Barcelo and Jannes propose a thought experiment of a hypothetical universe based on a massless scalar field with the properties of a superfluid sonic medium that propagates sound at a sonic speed designated (c_s). Particles are visualized as sonic quasi-particles (solitons) in this sonic field. They ask the question "Is an inertial observer capable of discerning whether he is at rest in the medium or moving through it at a certain uniform velocity?" To answer this question, they propose the sonic equivalent of the Michelson-Morley experiment [10]. They show that "the physical length of a quasi-interferometer arm, as measured in the lab (using acoustic instruments) would shrink by an acoustic Lorentz factor $\gamma = \left(1 - v^2/c_s^2\right)^{-1/2}$ when moving at a velocity v with respect to the medium". In other words, the acoustic universe model achieves not only a constant speed of sound (analogous to our constant speed of light), but it is also impossible to detect motion relative to the medium using an interferometer incorporating sonic quasi-particles and the sonic transfer of forces.

The second article is "*Sonic Clocks and Sonic Relativity*" by Todd and Menicucci [11]. They describe a thought experiment in which "sonic observers" possess devices called "sound clocks" that are analogous to Einstein's light clocks. Motion, relative to chains of these sonic clocks, are shown to undergo relativistic length contraction and time dilation. The article states, "moving observers perceive stationary sound clock chains to be length contracted and time dilated exactly as one would expect from a naïve application of the relativistic formula with c being the speed of sound instead of the speed of light." [11] The third article by D. Shanahan [12] refutes objections to the sonic universe model and shows that wave-based elementary particles in the sonic universe do a good job explaining the physical origin of the Lorentz transformation.

These referenced articles prove that a universe based on waves can intrinsically achieve Lorentz transformations. John Wheeler's spacetime foam (oscillating spacetime) has the property of a sonic medium. A sonic medium must have elasticity. This is the ability to absorb energy and return energy as a wave propagates through the medium. This article will explore whether it is possible to start with oscillating spacetime and achieve a plausible sonic quasi-particle. For example, is there any macroscopic examples of waves exhibiting wave-particle properties similar to an electron? The answer is yes, but first we must calculate some properties of this medium.

4. Oscillating Spacetime's Acoustic Properties

John Wheeler concluded that vacuum zero-point energy and the uncertainty principle both would be explained by spacetime being a medium that has Planck length (L_p) oscillations at Planck frequency (ω_p). Here we will take this description and calculate a few acoustic properties of such a medium. First, what speed should waves propagate within this medium? For example, the speed of sound in a gas is set by the thermal velocity of the atoms or molecules. Similarly, the speed of sound in oscillating spacetime is set by the speed of the spacetime oscillations. The exact model of oscillating spacetime is not clear, but in general it involves a sea of harmonically oscillating volumes of space approximately L_p in radius. These are oscillating at Planck frequency (ω_p) as measured by the local rate of time. Planck length times Planck frequency equals the speed of light ($L_p\omega_p = c$). While the details are not defined, this approximately satisfies the requirement that oscillating spacetime must propagate waves at the speed of light. Next, we will calculate the impedance (Z) of this medium. We start with the standard equation for the intensity ($I = kA^2\omega^2 Z$) of a wave with amplitude (A), angular frequency (ω) and impedance is Z. The intensity of a wave is $I = Uc$ where U is energy density and propagation speed is c. Combining these equations and solving for impedance (Z), we obtain

$$Z = k\frac{Uc}{A^2\omega^2}. \tag{1}$$

We know the spectral energy density of zero-point energy is $U_0(\omega) = \hbar\omega^3/2\pi^2c^3$ [1], and its integral can be defined as:

$$U_{\text{ZPE}} = \int_{\omega_1}^{\omega_2}\frac{\hbar\omega^3}{2\pi^2c^3}\text{d}\omega = \frac{1}{8\pi^2}\frac{\hbar}{c^3}\left(\omega_2^4 - \omega_1^4\right) \Rightarrow k\frac{\hbar\omega^4}{c^3}. \tag{2}$$

Equation (2) 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 (2) 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 is $1/8\pi^2$. However, we are interested in understanding the approximately 10^{122} discrepancy between the observed energy density of the universe ($\sim 10^{-9}$ J/m^3) and Planck energy density ($U_\text{p} = c^7/\hbar G^2 \approx 10^{113}$ J/m^3) implied by quantum field theory. We will be addressing the big picture and ignoring numerical constants near 1. Therefore, from Equation (2) $U = \hbar\omega^4/c^3$. Also, the wave amplitude equals Planck length ($A = L_\text{p} = (\hbar G/c^3)^{1/2}$). Making these substitutions into Equation (1), we obtain Equation (3),

$$Z_\text{d} = \left(\frac{\hbar\omega^4}{c^3}\right)\left(\frac{c^3}{\hbar G}\right)\frac{c}{\omega^2} = \frac{c\omega^2}{G} = \frac{c^3}{G\lambda\!\!\!^{-}{}^2}. \tag{3}$$

The "displacement impedance" of oscillating spacetime ($Z_\text{d} = c^3/G\lambda\!\!\!^{-}{}^2$) has kg/s·m^2 unit. This is the same unit as specific impedance. Notice that Z_d incorporates angular wavelength squared ($\lambda\!\!\!^{-}{}^2$). This means that the acoustic properties of oscillating spacetime depend on the wavelength (frequency) of the propagating wave. For unit compatibility, the "displacement impedance" is required when amplitude (A) has a unit of length (meter). For example, Equation (3) used L_p as the wave amplitude ($A = L_\text{p}$). This has unit of length (meter).

The strain impedance of spacetime (Z_s) is calculated as

$$Z_\text{s} = \left(\frac{\hbar\omega^4}{c^3}\right)\left(\frac{c^3\lambda\!\!\!^{-}{}^2}{\hbar G}\right)\frac{c}{\omega^2} = \frac{c^3}{G} = 4.04\times10^{35}\ \text{kg/s}. \tag{4}$$

Equation (4) generates the strain impedance $Z_\text{s} = c^3/G$ with unit of kg/s. It is common to use particle displacement (meter) to express the amplitude of a sound wave in a gas or liquid. However, wave amplitude can also be expressed as a dimensionless number corresponding to the maximum slope of a sine wave. For example, if the wave's displacement amplitude (A_d) is specified in meters, then the dimensionless strain amplitude is $\mathcal{A}_s = A_d/ƛ$. The script symbol $\mathcal{A}$ is used to designate amplitude expressed as a dimensionless number. When an interferometer is used to detect GWs, the observed amplitude is expressed as $\Delta L/L$ where ΔL is the length change in an interferometer caused by the GW and L is the round-trip path length of the interferometer [13] [14]. This is an approximation that requires the GW to have a wavelength much longer than the round-trip path length of the interferometer. The exact slope used in mathematical analysis requires that we define dimensionless strain amplitude as ($\mathcal{A}_s \equiv A_d/ƛ$). Interferometers measure the approximation $\Delta L/L$. When amplitude is dimensionless slope, then impedance with unit of (kg/s) must be used for compatibility. Equation (3) used the substitution $A^2 = A_d^2 = L_p^2 = \hbar G/c^3$ and that substitution generated displacement impedance of spacetime: $Z_d = c^3/Gƛ^2$. Equation (4) calculates the strain impedance of spacetime (Z_s) using the substitution $A^2 = \mathcal{A}_s^2 = L_p^2/ƛ^2 = \hbar G/c^3ƛ^2$. This generates the strain impedance $Z_s = c^3/G$. with unit of kg/s.

It is easy to extend these acoustic properties of spacetime to obtain useful acoustic properties such as density, energy density and bulk modulus. However, it must be remembered that oscillating spacetime is a universal field that requires the addition of an excitation to make density and energy density observable. Without this excitation (discussed below plus Sections 9 and 19) all the properties of this field are virtual. It is easy to obtain the density encountered by a wave propagating if we know the displacement impedance (Z_d) and propagation speed (c) because $\rho = Z_d/c$. The density will be designated "virtual density ρ_v" and can be defined as

$$\rho_v \equiv k\frac{Z_d}{c} = k\frac{\omega^2}{G} = k\frac{L_p^2}{ƛ^2}\rho_p. \tag{5}$$

This Equation (5) gives the virtual density encountered by a wave that propagates in oscillating spacetime. Equation (6) converts this virtual density to virtual energy density U_v,

$$U_v = K_v = k\rho_v c^2 = k\frac{F_p}{ƛ^2} = k\frac{c^2\omega^2}{G} = k\frac{L_p^2}{ƛ^2}U_p. \tag{6}$$

Since this is an ideal acoustic medium, the virtual energy density equals the virtual bulk modulus (K_v) of the medium. Note that Equations (5) and (6) convert to several other useful forms. In particular, the virtual energy density (U_v) encountered by a wave with angular wavelength $ƛ$ is $U_v = (L_p/ƛ)^2 U_p$ where $U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3. It should be noted that there is a similarity between the virtual energy density ($U_v = kF_p/ƛ^2$) of the quantum vacuum in Equation (6) and the energy density of a black hole ($U_{bh} = kF_p/r_s^2$) where r_s is the Schwarzschild radius of the black hole.

Now we can test Equations (4)-(6) because GWs propagate in the medium of oscillating spacetime. If we assume that GWs are propagating in a physical medium, then it is possible to determine the properties of the medium from GW equations. This was first done in books on GWs [13] [14]. The authors of Ref.

[13] mentioned, "Starting from Einstein's field equation … the coupling constant $c^4/8\pi G$ can be considered a metrical stiffness (see Sakharov 1968 [15]) … 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 Ref. [14] on GW detectors. Neither of these Refs. show how the "analogy with acoustic waves" generates the implied impedance c^3/G. However, the derivation is obvious. Both Refs. [13] [14] state

$$I=\left(\frac{1}{16\pi}\right)\left(\frac{\Delta L}{L}\right)^2\omega^2\left(\frac{c^3}{G}\right)\text{kg/s}^3\ . \tag{7}$$

Equation (7) is the equation for the intensity of a GW in the limit of a weak plane wave. The terms in Equation (7) have been arranged in a sequence that corresponds to

$$I=kA^2\omega^2 Z\ . \tag{8}$$

Equation (8) is the general equation for the intensity (I) of a wave with numerical constant (k), amplitude (A), frequency (ω) and impedance (Z). Comparing Equations (7) to (8), it is obvious the terms match and the impedance term is

$$Z_s\equiv\frac{c^3}{G}=m_p\omega_p=4.04\times10^{35}\ \text{kg/s}\ . \tag{9}$$

Equation (9) is the impedance encountered by GWs. This exactly matches Equation (4), the previously calculated impedance of oscillating spacetime. This is a successful test! GWs encounter the same impedance (c^3/G) as the predicted model of oscillating spacetime (Planck length oscillations at Planck frequency).

We can do one more test. We can calculate the energy density of Planck frequency oscillations ($\omega = \omega_p$), impedance ($Z = Z_s$) and dimensionless amplitude ($\mathcal{A} = A_d/\lambda\!\!\!^- = L_p/L_p = 1$). This dimensionless form of amplitude must be used for compatibility with strain impedance (Z_s). The equation to be used is ($U = kA^2\omega^2 Z/c$). Making these substitutions and assuming $k = 1$, the energy density is $U = c^7/\hbar G^2 \approx 10^{113}$ J/m^3. This is the correct answer, but it needs a physical interpretation. This is proposed to be the foundation of all fields. Fields only become observable when an "excitation" is introduced. The 10^{113} J/m^3 is a virtual energy density. Oscillating spacetime has a unit of energy density when mathematically analyzed, but it lacks the excitations required to convert a field into observable fermions or bosons. *The missing excitations are quantized units of angular momentum (ħ or ħ/2).* This will be shown in Section 9 for an electron and Section 19 for a photon.

5. Quantum Vortex Solitons Have Wave-Particle Properties

When a wave has particle-like properties, it is designated a soliton. A soliton is a nonlinear, self-reinforcing, localized wave packet that is strongly stable. For example, solitons are unaltered in shape and speed by a collision with other solitons [17]. Most soliton waves propagate linearly, but there are also rotating solitons. The closest analogy to the wave-based electron model is a rotating quantum vortex (a rotating soliton) in a superfluid such as superfluid liquid helium or a superfluid Bose-Einstein condensate. **Figure 1** shows several images of rotating soliton waves in a Bose-Einstein condensate [16]. When angular momentum is introduced into a superfluid using two rotating laser beams, it creates multiple rotating quantum vortices that are solitons. For example, if a small amount of angular momentum is introduced into the superfluid, the angular momentum is not distributed through the entire mass of superfluid. Instead, the angular momentum is quarantined into small rotating "quantum vortices" while the bulk superfluid does not rotate. Each quantum vortex has a quantized angular momentum term incorporating $\hbar$.

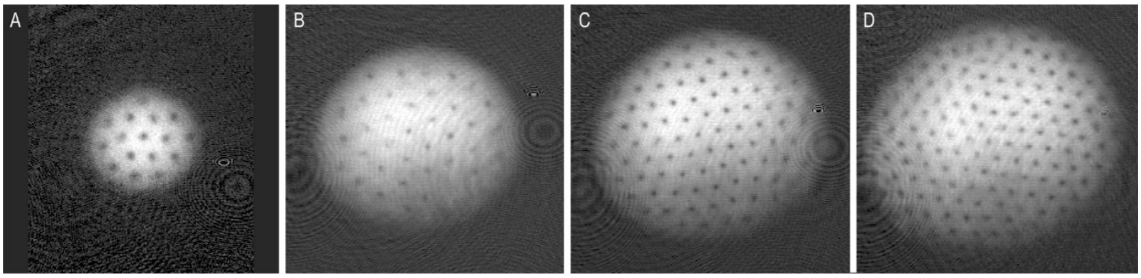

Figure 1. These are images of rotating quantum vortices in superfluid Bose-Einstein condensate droplets. Frame A has about 16 rotating vortices and frame D has about 130 vortices. Each vortex possesses a unit of quantized angular momentum incorporating $\hbar$ [16].

Notice the geometric pattern the rotating vortices make. Immediately after stirring with two rotating laser beams for about a tenth second, these vortices have a random distribution [16]. However, over about the next second, these vortices assemble themselves into the geometric pattern shown in **Figure 1**. This pattern is known as a "triangular lattice" or "hexagonal lattice". This pattern reveals there must be a repulsive force between each vortex. The vortices arrange themselves in the geometric pattern that achieves the greatest distance between vortices but within the droplet boundary. This has an obvious similarity to electrostatic repulsion between electrons. Apparently, each rotating vortex distorts the surrounding superfluid in such a way that the lowest energy state is achieved at the maximum separation distance between vortices.

There is an obvious connection to the electron model. If it was possible to suspend 130 electrons in a single X-Y plane with a circular boundary, (analogous to Fig. D), their electrostatic repulsion would arrange the electrons into the lowest energy state. This would be a triangular lattice pattern like **Figure 1(D)**. The difference is a superfluid droplet with a surface boundary generates rotating vortices. The superfluid Universal field with no surface boundary generates rotating spherical waves. The repulsion between the vortices in **Figure 1** is action at a distance transferred by a distortion of the surrounding superfluid. The electron model developed later will also be shown to transfer its electrostatic and gravitational forces through a distortion of the surrounding medium (oscillating spacetime).

The rotating quantum vortices shown in Figure 1 are shown because they have similarities to the simplified electron model that will be proposed later. Then the simplified electron model will be expanded to allow it to achieve an electron's wave functions. However, first, a more complete description of the oscillating spacetime model will be given. Then the electron model will be developed, starting with the simplified model. The electron model will build on analogies to the quantum vortices of Figure 1.

6. Description of Oscillating Spacetime

Wheeler's concept of oscillating spacetime [7] can be condensed into the following two postulates.

1) The quantum vacuum is a sea of Planck length vacuum oscillations at Planck frequency.

2) These oscillations create vacuum zero-point energy and the uncertainty principle.

In addition to these, the following postulates are proposed.

3) These spatial and temporal oscillations make spacetime a stiff elastic sonic medium that propagates waves at the speed of light.

4) This medium has a privileged frame of reference where the medium is truly at rest. This privileged frame corresponds to the local cosmic microwave background (CMB) rest frame.

5) This oscillating spacetime is the single medium that generates everything in the universe—all fermions, all forces, all other fields and all the laws of nature.

6) All fields are lower frequency resonances and distortions of the ω_p oscillating spacetime.

7) An electron is a soliton wave, rotating in the oscillating spacetime. This rotating wave has $\hbar/2$ angular momentum (Z axis) with undetectable displacement amplitude of L_p.

We will start by giving a more detailed description of oscillating spacetime. On the scale of a volume with a radius of approximately L_p, spacetime has the properties of a harmonic oscillator. This volume undergoes both spatial and temporal oscillations at ($\omega_p \approx 10^{43}$ rad/s). An adjacent volume probably oscillates out of phase so that there is offsetting expanding and contracting volumes. Therefore, even describing the size as approximately L_p in radius is a problem because the coordinate distance between points fluctuates. The fluctuations are happening at the speed of light. Therefore, a wave in this medium will also propagate at the speed of light. This satisfies the first requirement for the universe to be a sonic universe. The speed of sound of the sonic medium must equal the speed of light.

The Planck frequency oscillations give oscillating spacetime its 4^th^ dimension (its time dimension). Every point in spacetime needs a local clock to enforce the local rate of time. The constants c, G and $\hbar$ all have time in their units. The rate of time is affected by gravity and frame of reference. The oscillations of oscillating spacetime are required to impose a local rate of time and generate the constants c, G and $\hbar$. The oscillation frequency, measured locally, always equals Planck frequency.

These oscillations include a fluctuation of the rate of time on the scale of Planck length. A comparison of two hypothetical perfect point clocks separated by more than L_p 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 following thought experiment will help to explain the proposed spacetime 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.

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 spacetime model to be tested has spatial and temporal fluctuations between positive and negative energy distortions. Adjacent volumes probably oscillate out of phase, so these average to zero observable energy and zero average distortion. Therefore, the macroscopic average appears to be a quiet vacuum with no observable energy. These oscillations give the quantum vacuum its physical properties (natural laws) that include the constants of c, G and $\hbar$.

Spherical volumes with radius much larger than Planck length ($r > L_p$) contain vast numbers of these L_p harmonic oscillators. Collectively, they also produce a "noise" that is a distributed L_p fluctuation across the radius r at the lower frequency of $\omega = c/r$. These larger volumes also achieve the virtual energy of $E = \hbar\omega/2$ of zero point energy oscillators. As discussed later in Section 9, a few frequencies are resonances. For example, the resonance at $\omega = 7.8 \times 10^{21}$ rad/s is associated with both real electrons and virtual electrons. A virtual electron is a distortion of oscillating spacetime that momentarily achieves an electron's properties. However, this distortion disappears in $1/\omega_c \approx 10^{-21}$ seconds. The reason proposed here is that it lacks the quantized angular momentum required to achieve the stability and energy of a real wave-based electron.

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 [18]-[21]. 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. Also, the proposed model of oscillating spacetime gives spacetime its time dimension. The Planck length/time fluctuations just described are not a field that occupies empty spacetime. Instead, spacetime *is* an oscillating sonic medium. All fermions will be shown to be sonic soliton waves in this medium. This meets the requirement described in [10]-[12] to achieve Lorentz transformations. All the fields of quantum field theory are proposed to be resonances or distortions of oscillating spacetime. This is the ultimate simplification and unification.

7. De Broglie Waves

Richard Feynman famously said that, "The double-slit experiment has in it the heart of quantum mechanics. In reality, it contains the only mystery." [22]. 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. This was first predicted by Louis de Broglie in his 1924 PhD thesis. This prediction has been confirmed by numerous experiments. (Google Scholar lists over 1000 articles on de Broglie waves or matter waves.) Therefore, a key requirement of a wave-based electron model is that it must exhibit these wave-like properties. In a frame of reference moving at velocity v, the model must achieve the following: 1) the electron's de Broglie angular wavelength ($\lambda\!\!\!^{-}_{d} = \hbar/p = \hbar/\gamma m_e v$); 2) the de Broglie phase velocity ($v_{\text{phase}} = c^2/v$); 3) the de Broglie group velocity of ($v_{\text{group}} = v$).

In the Introduction, it was mentioned that the initial motivation for starting this research was the realization that the confined waves inside a laser had 5 quantum mechanical and relativistic properties of particles. Normally, light waves freely propagate at the speed of light with no frame of reference. However, the light inside a laser reflects between two mirrors. This creates standing waves inside the laser and gives this confined light a specific frame of reference. When light is forced to have the particle-like property of a specific frame of reference, it also exhibits 5 other particle-like properties. In a moving frame of reference, this confined light also exhibits 1) de Broglie waves, 2) relativistic length contraction, 3) relativistic time dilation, 4) relativistic kinetic energy, and 5) inertia when accelerated. This is proven mathematically in references [23]-[25]. However, computer simulations give a conceptual understanding that even helps understand the mathematical analysis.

A laser has an integer number of counter propagating light wavelengths reflecting between its two mirrors. These counter propagating waves form standing waves between the mirrors. In a single frequency laser in a stationary frame of reference, the amplitude of these waves oscillates in unison. If phase is ignored, the amplitude of these standing waves appears to oscillate at twice the laser's optical frequency. However, when phase reversal is included, one complete cycle equals the optical frequency. **Figure 2** shows a laser moving from left to right at about 5% speed of light. This figure depicts how the standing waves would appear if they could be observed at an instant of time in this moving frame of reference.

Waves moving in the direction of relative motion are Doppler shifted to a higher frequency (shorter wavelength) and waves moving in the opposite direction are doppler shifted to a lower frequency. The superposition of these waves creates the modulation envelope shown in **Figure 2**. The modulation envelope pattern is moving to the right at a phase velocity of c^2/v. For the example depicted ($v = 0.05c$), the modulation envelope would be moving to the right at 20 times the speed of light. This is an interference effect equivalent to a moire pattern that can move faster than the speed of light without violating any laws of physics. The waves that form this pattern are real; the moire pattern (modulation envelope) is ethereal. The modulation envelope wavelength (λ_m) in **Figure 2** matches the electron's de Broglie wavelength if the optical wavelength equals the electron's Compton angular wavelength $\bar{\lambda}_c = \hbar/m_e c = 3.86 \times 10^{-13}$ m. What happens if there are spherical standing waves rather than linear standing waves?

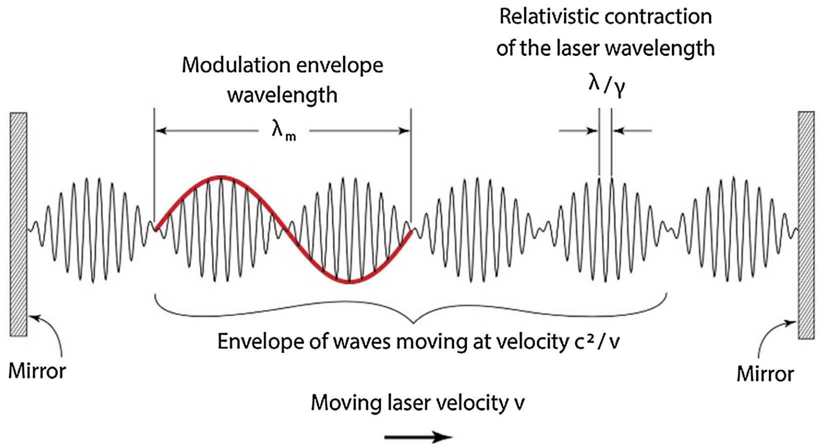

Figure 2. The standing waves in a laser exhibit this modulation envelope when the laser is translated at 5% the speed of light. This modulation envelope wavelength (λ_m) would equal an electron's de Broglie wavelength if the laser wavelength equaled an electron's Compton wavelength. These standing waves also have relativistic length contraction.

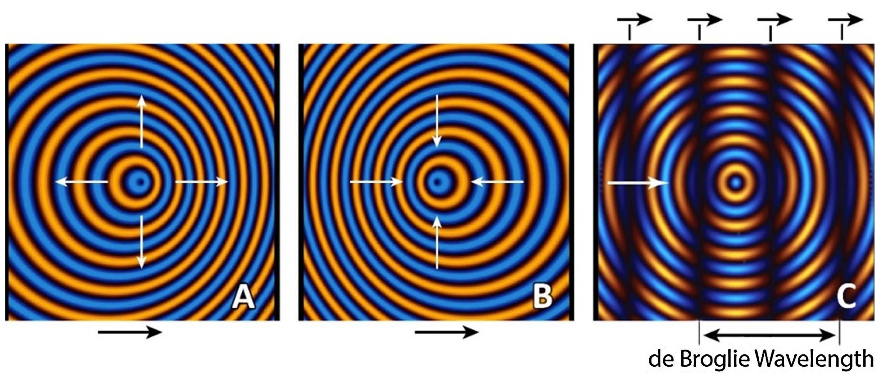

Figure 3. The A and B panels are Doppler distorted spherical waves moving to the right at 25% the speed of light: In (A), the waves are propagating outward from a central source and in (B) the waves are propagating inward towards a central point. (C) is a superposition of (A) and (B). The moving linear interference pattern in (C) has similarities to an electron's de Broglie wave properties if the waves have an electron's Compton wavelength in the rest frame. See the wave animation video at: https://www.quantizedwave.com/video.

The mirrors in Figure 2 reflected the laser light and achieved the standing waves inside the laser. Figure 3 assumes an unseen reflection mechanism such as a spherical mirror which reflects the outward propagating waves back towards the central source of the waves. The 3 panels in Figure 3 assume the source of these waves and the reflector are moving to the right at 25% the speed of light. Figure 3(A) shows just the outward propagating waves and Figure 3(B) shows just the inward propagating waves. The relative motion (25% of c) produces the Doppler distortion of these waves. Figure 3(C) is the superposition of panels 3(A) and 3(B). The dark bands in Figure 3(C) are regions of destructive interference. These are equivalent to the amplitude minimums (≈0 amplitude) in Figure 2. Notice that there is a 180-degree phase reversal at these dark bands. For example, notice that a yellow standing wave segment changes to a blue standing wave segment going across a dark band. This indicates a 180-degree phase reversal. In Figure 2, there also is a phase reversal going through a minimum amplitude, but the difference in phase is not as noticeable as in Figure 3. The point of these figures is to graphically show how spherical standing waves with a wavelength equal to an electron's Compton angular wavelength achieve an electron's de Broglie wave properties. References [23] and [24] prove that confined light in a moving frame of reference not only exhibits de Broglie waves, but also exhibits relativistic length contraction, relativistic time dilation and relativistic energy increase. Reference [25] shows confined light exhibits inertia. For example, if a laser is accelerated along its optical axis, there is unequal light pressure on the two reflectors. The acceleration means that higher frequency light strikes the rear reflector compared to the front reflector. This produces a net force that resists acceleration. This is the inertia of the confined light energy. No Higgs field is required to give inertia to confined waves.

8. The Simplified Electron and Muon Model

The proposed wave-based model of an electron and other fermions is fundamentally a rotating soliton wave in the medium of oscillating spacetime. The following description will focus on the simplest wave-based fermion, an electron. The wave that forms an electron can have many different shapes, sizes and characteristics depending on the interactions with other fermions and boundaries. Therefore, the description of an electron will start with a simplified model of an isolated electron in its most compact form. This compact model allows calculations to be made such as an electron's energy, wave properties and forces. Later in Section 18 there will be a brief discussion of how this quantized wave can expand and contract to other sizes and shapes.

There is an analogy between the proposed wave-based model of an electron and a rotating quantum vortex previously described in Figure 1. It was shown that when angular momentum is introduced to the superfluid Bose-Einstein condensate, it forms rotating vortices. Each vortex in this superfluid is a rotating soliton wave possessing quantized angular momentum incorporating $\hbar$. These quantum vortices arrange themselves in a pattern indicating each vortex repels its neighbors by distorting the surrounding superfluid.

Oscillating spacetime is a perfect superfluid. When quantized angular momentum is introduced into oscillating spacetime, it can form a rotating soliton wave with similarities to the quantum vortices of **Figure 1**. Oscillating spacetime has resonances that form stable or semi-stable rotating waves at specific frequencies. We will only be discussing electrons and muons. The rotating wave that forms an electron must form standing waves in the surrounding oscillating spacetime to achieve an electron's de Broglie wave characteristics. The previous analysis indicated an electron's de Broglie wave characteristics imply the existence of spherical standing waves with a frequency equal to an electron's $\omega_c = 7.76 \times 10^{20}$ rad/s. Therefore, the indication is that these standing waves probably are generated by a wave rotating at an electron's ω_c. The simplest electron model would be a rotating wave, approximately one Compton wavelength in circumference. This would have a radius equal to an electron's Compton radius ($r_c = \hbar/m_e c = 3.86 \times 10^{-13}$ m). This radius is also equal to an electron's Compton angular wavelength ($r_c = ƛ_c = \hbar/m_e c$). This simplified wave-based model of an electron is illustrated below.

The proposed wave-based model of an electron can be broken into two parts: 1) A core wave, rotating at an electron's ω_c and 2) the standing, rotating waves that surround this core wave. The rotating wave that forms an electron's core does not have a sharp edge. However, it has a "mathematical radius" equal to r_c. This mathematical radius is used in calculations. The energy in the electron's electric field, external to r_c, is $E_{ext} = \alpha\hbar c/2r_c \approx 3 \times 10^{-16}$ J. This is roughly 0.4% of an electron's total energy. There is also a roughly comparable energy in the electron's magnetic field. Therefore, it can be said that in this model, more than 99% of an electron's energy is in the rotating core and less than 1% of an electron's energy is in its electric/magnetic field.

Figure 4 shows two ways of attempting to illustrate the core wave of the electron model. This wave is completely unlike anything we have previously encountered. This is a 4-dimensional soliton wave rotating in oscillating spacetime. The enormous impedance of this medium ($c^3/G = 4\times10^{35}$ kg/s) makes it possible for this wave with undetectable displacement amplitude of Planck length/time to generate a testable electron model. The spatial aspect of the electron's core wave is represented by **Figure 4(A)**, while **Figure 4(B)** represents the temporal component. Both components are simultaneously present and form a single 4-dimensional rotating wave.

The representation in **Figure 4(A)** has three inaccuracies. First, the L_p spatial amplitude is about 10^{22} times smaller than an electron's Compton radius. Therefore, the wave's height depicted in **Figure 4(A)** is vastly exaggerated. Second, there appears to be an effect incorporating the fine structure constant that distorts the electron's core. This distortion is only partly understood and not incorporated into **Figure 4**. This effect will be discussed later in Section 17, but this $\alpha^{1/2}$ reduction may reduce the size of the core somewhat. The third inaccuracy is that **Figure 4** implies the rotation is in a single direction and plane. This is completely wrong. The rotating wave that forms an electron only distorts oscillating spacetime by Planck length. It exists in a turbulent sea of L_p spatial and Planck time temporal fluctuations that cause distortions. Furthermore, this wave is at the limit of causality. It has an expectation rotational direction and axis, but this rotation is chaotic. It also rotates around all other axes with a lower probability amplitude than the expectation axis. Only the reverse of the expectation rotational direction has a probability of zero.

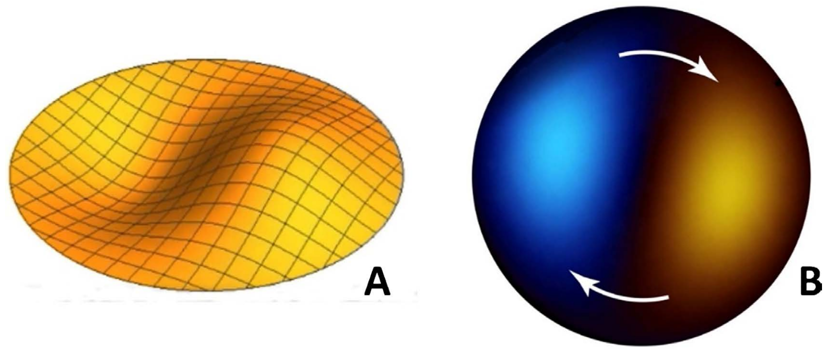

Figure 4. Two different ways of representing the rotating distortion of oscillating spacetime that is the core of the wave-based model of an electron. (A) represents the distortions of space and time as a distorted membrane. (B) uses blue and yellow to represent spatial and temporal distortions. The arrows in (B) imply rotation. The blue and yellow areas indicate the wave maximum and minimum of the soliton wave that forms an electron's core. The rotation rate is equal to an electron's Compton frequency ≈ 10^{20} Hz.

Now we will switch to attempt to explain how the electron's core wave also modulates the rate of time (the 4th dimension). To illustrate this, we will utilize blue and yellow colors in **Figure 4(B)**. Imagine the blue lobe of **Figure 4(B)** represents a volume of space where the rate of time is faster than the local norm and the yellow lobe has a slower rate of time than the local norm. The temporal distortion is ± Planck time ($\pm 5 \times 10^{-44}$ s) displacement of the temporal dimension. For every radian of rotation of the wave, a hypothetical clock in the blue lobe would gain one unit of Planck time ($\sim 10^{-43}$ s) and a clock in the yellow lobe would lose one unit of Planck time. This imperfect example is compared to the local norm. The wave is rotating at $\omega_c = 7.76 \times 10^{20}$ rad/s, therefore the blue lobe would have a faster rate of time of $t_p \omega_c = 4.18 \times 10^{-23}$ seconds per second compared to the local norm and the yellow lobe loses time at this rate. This is an extremely small difference in the rate of time. For example, if two perfect clocks differed by this amount, they would only differ by about 40 microseconds over the age of the universe.

The rotating wave in the core of an electron is technically a "dipole wave in spacetime". Macroscopic dipole waves are forbidden by general relativity. For example, a standard text on general relativity [7] states that *there can be no mass dipole radiation because the second time derivative of mass dipole is zero*. For example, if dipole waves existed in spacetime on the macroscopic scale, they would violate the conservation of momentum. However, it is proposed here that the uncertainty principle permits dipole waves to exist in spacetime if they are undetectable. It has been theoretically proven that it is impossible to make measurements accurate to L_p or t_p, [18]-[21]. Therefore, quantum mechanics permits the dipole waves in spacetime required for the wave-based model of fermions.

A sound wave in a sonic medium has an amplitude that can be quantified as the maximum displacement of the vibrating particles from the mean position. This has been designated "displacement amplitude (A_d)" and it has unit of length (meter). The previously discussed alternative way of expressing the amplitude of a sine wave is its strain amplitude ($\mathcal{A}_s = A_d/ƛ$). This is the dimensionless maximum slope of the sine wave. The maximum slope of the rotating wave that forms an electron will be designated the "electron's strain amplitude ($\mathcal{A}_e = 4.185 \times 10^{-23}$)". It is a dimensionless number obtained by dividing electron's displacement amplitude (L_p) by the electron's Compton angular wavelength ($ƛ_c = \hbar/m_e c = 3.86 \times 10^{-13}$). Therefore $\mathcal{A}_e = L_p/ƛ_c = 4.18 \times 10^{-23}$. This dimensionless number will be shown to also represent all the electron's properties (expressed in dimensionless Planck units) except for the electron's EM properties.

9. The Source of an Electron's Fields

Now, we are going to move on to describe another part of the simplified electron model. If we actually had a rotating hill and valley on a membrane, such as shown in Figure 4(A), then an extended elastic membrane would propagate a sinusoidal Archimedean spiral wave, radiating away from the source. Figure 5(A) shows an outward radiating sinusoidal Archimedean spiral wave. The clockwise rotating source of these waves is not shown. For example, the yellow spiral waves in Figure 5(A) can be visualized as hills and the blue spiral waves can be visualized as valleys. These waves would move outward from the central source at the speed of surface wave propagation (c for an electron).

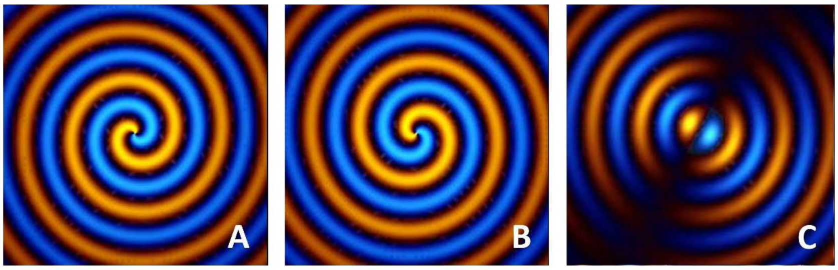

Figure 5. Both (A) and (B) represent clockwise rotating sinusoidal Archimedean spirals. (A) is outward propagating Archimedean spiral waves emanating from a central rotating wave. (B) is the inward propagating (reflected) spiral waves. (C) is the superposition of the outward and inward traveling waves to form standing waves in (A) and (B). This shows a central rotating core wave surrounded by rotating standing waves. (C) is a cross-section of the model of an electron.

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 inward propagating spiral waves in Figure 5(B) appear to imply a reversal in rotational direction, but this is a wrong interpretation. Figure 5(B) also has a clockwise rotation but the inward propagation produces this spiral. Figure 5(C) is the superposition of the outward and inward propagating waves. This figure should be rotating at an electron's Compton frequency, ~10^{20} Hz. The central core is surrounded by the rotating standing waves that create an electron's electric and magnetic field. The distortion that creates an electron's gravitational field is not shown. This is a cross section of the simplified wave-based model of an electron.

As previously justified, about 99% of an electron's energy is in the electron's central core and less than 1% of the electron's energy is in the rotating standing waves. Beyond the core, these waves decrease in amplitude with inverse radius ($1/r$) and never go to zero. Therefore, an electron's "cloud" of standing waves extends indefinitely. There is no mystery about action at a distance in this model. A first electron's standing waves physically overlap a distant second electron. Each electron distorts the oscillating spacetime medium used by the other electron. When a rotating wave such as an electron rotates in a distorted medium, the distortion causes the rotating wave to migrate either away from or towards the other rotating wave. This results in the transfer of a force through a distortion of oscillating spacetime. Two electrons migrate away from each other (repel each other), but an electron and a positron migrate towards each other. The difference appears to be a difference in phase, perhaps at the level of ω_p. This is currently not understood. However, the key point is that the force is transferred through the medium. Recall the repulsion between quantum vortices in a Bose-Einstein condensate previously discussed in relation to Figure 1. They appear to also repel each other through a distortion of the medium. There is no need to postulate the exchange of virtual messenger particles.

Figure 5(A) to Figure 5(C) were made using a sinusoidal Archimedean spiral. 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 unit of length. The electron model used for illustrations is based on an Archimedean spiral with $a = r_c$. Therefore, the electron's Archimedean spiral equation is $r = r_c\theta$.

Figure 5(C) is believed to be a fairly accurate depiction of the electron's rotating standing waves beyond about one Compton wavelength. However, there is an effect discussed in Section 15, involving vacuum polarization that reduces the amplitude of the waves beyond the core by a factor of $\alpha^{1/2} \approx 0.085$. The electron model shown in Figure 5(C) depicts the electron model without the effect of vacuum polarization. Without this effect, an electron would generate Planck charge (q_p) rather than charge $e = \alpha^{1/2}q_p$. This reduction in amplitude probably also reduces the size of the core somewhat. The ($1/r$) reduction in wave amplitude is also not shown to depict the electron's external rotating standing waves more clearly.

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 oscillating spacetime in which rotating standing waves in **Figure 5(C)** become their own reflectors. Waves attempting to escape are returned to the core. There are only a few combinations of frequencies, amplitudes, angular momentum, etc. that achieve stability (this resonance). These are the stable fundamental fermions and baryons.

In Bragg reflection, electromagnetic (EM) waves in a transparent medium reflect off acoustic waves [26]. In stimulated Brillouin scattering, an intense laser beam creates the acoustic waves in a medium that then reflects the laser beam in the opposite direction [26]. The simplest type of resonant reflection would be for a wave to create a density variation (like a multilayer dielectric reflector) that reflects the 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, the electron model has two different communication speeds. Some internal communication happens at the same speed as entanglement communication (instantly). Other communication happens at the speed of light. For now, it is only necessary to postulate the existence of standing waves and calculate the results of these standing waves.

10. Zitterbewegung

In 1930, Erwin Schrodinger [27] 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 [28], "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* [29], 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." This describes the rotating wave that forms an electron's core depicted in **Figure 4** and **Figure 5**. The chaotically rotating wave is moving at the speed of light with a mathematical radius equal to the electron's Compton radius (r_c).

The frequency of an electron's zitterbewegung is twice the electron model's Compton frequency (ω_c). However, this is compatible with the proposed electron model because the waves in **Figure 5** are the electron's wave function and the electron's zitterbewegung is analogous to the electron's probability function (intensity) that scales with the square of the wave function ($\sin^2\theta = ½(1 - \cos 2\theta)$). This squaring doubles the frequency to 2θ. Therefore, the zitterbewegung should be twice the wave function frequency. The quantized rotating wave is moving at the speed of light. However, the interference effects move at both less than and greater than the speed of light. The electron's zitterbewegung oscillations extend far from the core and are a component of the electron's EM and gravitational fields. The quantized wave-based model is a natural fit to the Dirac equation and de Broglie waves. Electron models incorporating a point particle, or point excitation, are an arduous fit.

11. Energy Calculation

We are next going to test the wave-based electron model by calculating the energy of the electron model. This is believed to be the first time an analytical electron model has been proposed with sufficient detail that it is possible to calculate the implied energy. Recall that this wave-based model of an electron is simplified to permit calculations. There are several ways of doing this calculation. The most direct uses the equation $E = kA^2\omega^2 ZV/c$. This equation gives the energy (E) of a wave with amplitude A, frequency ω, in volume V propagating at speed c and encountering impedance Z. If we substitute $A = \mathcal{A}_e = L_p/r_c = \left(Gm_e^2/\hbar c\right)^{1/2}$, $\omega = \omega_c = c/r_c = m_e c^2/\hbar$, $Z = c^3/G$, $r_c = \hbar/m_e c$ and $V = kr_c^3$, then, ignoring numerical constants near 1, the answer equals an electron's $E = m_e c^2$ energy

$$E = k\frac{A^2\omega^2 ZV}{c} = k\frac{Gm_e^2}{\hbar c}\left(\frac{m_e c^2}{\hbar}\right)^2\frac{c^3}{G}\left(\frac{\hbar}{m_e c}\right)^3\frac{1}{c} = m_e c^2. \quad (10)$$

Equation (10) shows this is a successful test because the wave-based electron model generates electron's approximate energy (approximate because we ignored k). If we were calculating a muon's energy, there would be different values for a muon's amplitude, frequency, and volume. This combination yields a muon's energy in Equation (10). The point particle models of electrons and muons have no internal structure. These are primitive models that make no structural difference between an electron, a muon or any other fermion.

I want to put this energy calculation into perspective. This model's electron's energy density is about 3.4×10^{23} J/m^3. This is about 167 times the energy density of osmium ($\rho \approx 23$ gm/cm^3). The reason that a wave with L_p displacement amplitude can achieve this large energy density is because impedance $Z_s = c^3/G$ makes oscillating spacetime an extremely stiff wave propagation medium. A high frequency wave with a very small amplitude can have this energy density with this impedance. This enormous impedance makes it possible for a wave with an electron's Compton frequency (~10^{20} Hz) and L_p displacement amplitude to form an easily detectable electron. This is the "excitation" of the universal field that creates an electron.

However, this enormous impedance also means that GWs are hard to detect. Even GWs with substantial intensity produce a very small displacement of oscillating spacetime. For example, the first GW detected (GW150914) had an intensity of about 0.02 w/m^2 at about 200 Hz. This intensity would be a very loud tonal noise if it was a 200 Hz sound wave. However, this GW produced a nearly undetectable strain amplitude of only $\Delta L/L \approx 1.25 \times 10^{-21}$ in oscillating spacetime [30] [31]. Detecting this infinitesimal effect required the LIGO experiment; an interferometer with arms 4 km long.

12. Quantized Angular Momentum

Now that we have confirmed that the wave-based electron model achieves an electron's energy, we can calculate the approximate angular momentum of this rotating wave. A wave propagating at the speed of light with energy E, has momentum $p = E/c$. The electron model is a distributed wave. However, for an approximation, we can assume this wave is confined to only propagate in a narrow circular channel (hoop) with radius equal to an electron's Compton radius $r_c = \hbar c/E$. The angular momentum of a rotating hoop with radius r and momentum p is $\mathscr{L} = pr$. With these postulates, we have $\mathscr{L} = pr = (E/c)(\hbar c/E) = \hbar$. The electron's single axis angular momentum is $\hbar/2$ and the 3-axis angular momentum is $(3/4)^{1/2}\hbar \approx 0.87\hbar$. Therefore, this simple calculation is an approximate success. Notice that this calculation gives the same angular momentum for muons.

The rotating center of **Figure 5(C)** is an interference effect. Parts of this are moving slower than c and parts are moving faster than c. The faster than c component does not violate the laws of physics because an interference effect is the sum of two or more waves. The interference effect does not transfer information or energy faster than light. Only the underlying Archimedean spiral waves possess energy and momentum. Only the very small tangential component of these spiral waves carries angular momentum. The electron's 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 single axis net angular momentum to something less than $\hbar$. We are only looking for approximations, so $\hbar/2$ is plausible. A point particle has no radial dimension. Therefore, a point particle must have zero angular momentum.

13. Electron's Gravity

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 that slightly modify the original waveform. The finite air pressure sets a boundary condition that creates a very weak nonlinearity at conversational levels.

If oscillating spacetime could propagate waves without any frequency/wavelength limitation, there would be no nonlinearities. However, oscillating spacetime has finite properties that create a boundary condition. For example, oscillating spacetime cannot propagate a wave with a frequency exceeding ω_p or a wavelength less than L_p. This single boundary condition means that a sinusoidal wave in this medium will undergo a nonlinear distortion even for frequencies much less than ω_p (wavelengths much longer than L_p). This implies that even a wave-based electron with frequency $\omega_c = 7.8 \times 10^{20}$ rad/s should produce a small but quantifiable nonlinear distortion in oscillating spacetime. We will test this hypothesis and see if it explains the mechanics of how an electron creates curved spacetime and gravitational forces. Einstein just postulated that mass caused the curvature of space without explaining the underlying mechanism. The model proposed in this work also aims to provide the foundational explanation of how a fermion creates the gravitational curvature of spacetime.

The gravitational curvature of spacetime can be thought of as a slowing in the coordinate speed of light. From my laser background, I postulated there might be a similarity between gravitational slowing of the coordinate speed of light in oscillating spacetime and the optical Kerr effect that increases the index of refraction (slows light) in transparent materials. All transparent materials (all solids, liquids, and gases) exhibit a nonlinear effect known as the Kerr effect. The atoms that form a transparent material are bound by electric fields with a finite strength. This finite electric field strength is a boundary condition. Applying an electric field to a transparent material produces a nonlinear optical distortion that results in a change in the index of refraction ($\Delta n = \lambda K \mathcal{E}^2$) where λ is wavelength, K is the Kerr constant of the transparent material and $\mathcal{E}$ is the electric field [32]. Note that the magnitude of this nonlinear effect scales with electric field strength squared ($\mathcal{E}^2$). The nonlinearity reaches maximum when the imposed electric field equals the boundary (the binding electric field).

In the optical Kerr effect, the oscillating electric field of the light itself is the imposed electric field that produces a change in the index of refraction. Even low intensity light generates a weak nonlinear effect, but this nonlinearity went unnoticed until high intensity laser beams produced large nonlinear effects. This effect becomes obvious when the intensity of a focused laser beam is roughly about 1 GW/cm^2 [33]. In glass, the increase in index of refraction can be so great that the nonlinear index of refraction gradient can cause the beam to self-focus and prevents a focused laser beam from expanding beyond the radius of the high intensity focus. This is known as electrostrictive self-focusing [33].

This hypothesis implies that squaring the electron's strain amplitude ($\mathcal{A}_e^2 = \left(L_p/r_c\right)^2 = 1.75\times10^{-45}$) should be analogous to squaring the electric field ($\mathcal{E}^2$) in the optical Kerr effect. The prediction is that squaring the electron's strain amplitude should be the dominant first term in a nonlinear expansion that defines the nonlinear effect produced in an electron's core wave. A prediction is that multiplying electron's strain amplitude squared $\mathcal{A}_e^2$ by the electron's Compton radius ($\mathcal{A}_e^2 r_c = L_p^2/r_c$) should give the gravitational distortion produced by an electron. This predicted gravitational distortion will be designated the electron's "gravitational radius" r_G, which is equivalent to

$$r_G = L_p^2/r_c = 6.76\times10^{-58}\ \text{m}. \tag{11}$$

Equation (11) quantifies this prediction. It can also be written as $r_G = A_s^2 r_c$. This predicted r_G is half of an electron's Schwarzschild radius ($r_s = 2Gm_e/c^2 = 1.35 \times 10^{-57}$). General relativity was generated from a top-down approach that started with the assumption that acceleration and gravity were equivalent. "Einstein's happiest thought was his leap from the observation that a falling person feels no gravity to the realization that gravity might be equivalent to acceleration." [34] His successful general relativity addressed just the macroscopic properties of gravity and acceleration.

Equation (11) was generated by a bottom-up approach that started with oscillating spacetime being a nonlinear medium and the wave-based electron model causing a nonlinear distortion in this medium. This bottom-up approach reveals the underlying physics of how fermions create curved spacetime. It is possible to judge the validity of this approach by analyzing Equation (11). The left side of Equation (11) is a gravitational concept that conforms to the weak gravity approximation from general relativity because $r_G = Gm/c^2$. The right side of Equation (11) contains only quantum mechanical terms. ($L_p^2 = \hbar G/c^3$) and ($r_c = \hbar/mc$). Equation (11) is unique since it is the first equation to derive a gravitational property from a quantum mechanical structural model of a fundamental particle. The gold standard for validating a new theory is whether it is capable of making a prediction that can be proven correct.

The essential nature of a particle's gravitational radius is highlighted by the straightforward Equations (12) and (13)

$$g = r_G c^2 / r^2, \tag{12}$$

$$\frac{dt}{d\tau} = 1 + \frac{r_G}{r} = 1 + \frac{Gm_e}{c^2 r}. \tag{13}$$

An electron will be used in the explanation, but this applies to any fermion or even any hadron. Equation (12) incorporates r_G to generate the gravitational acceleration (g) produced by an electron at a distance $r > r_c$. Equation (13) incorporates r_G in an equation equivalent to the weak gravity approximation for the gravitational effect on the rate of time. The left side of Equation (13) is the gravitational rate of time gradient ($dt/d\tau$) produced by an electron. The right side of Equation (13) contains an electron's gravitational radius. The ratio r_G/r is the dimensionless slope of the gravitational curvature produced by an electron. This slope can also be written as $L_p^2/r_c r$ or $Gm_e/c^2 r$. Technically, Equation (13) is the weak gravity approximation. However, for an electron beyond its Compton radius ($r_c = 3.86 \times 10^{-13}$ m), this approximation is accurate to better than 1 part in 10^{40} and is being considered exact.[1]

As illustrated below, Equation (14) reveals there is a symmetrical relationship between $r_G{:}L_p{:}r_c$ because

$$\frac{r_G}{L_p} = \frac{L_p}{r_c}. \tag{14}$$

To understand this, imagine these three lengths are designated on a logarithmic length scale. The shortest length is an electron's r_G ($= 6.76 \times 10^{-58}$ m) and the longest length is an electron's Compton radius ($r_c = 3.86 \times 10^{-13}$ m). Planck length, ($L_p = 1.62 \times 10^{-35}$ m) is exactly midway between these two radii on the logarithmic length scale. This symmetrical relationship also applies to any fermion or even any hadron. A particle more massive than an electron has a larger gravitational radius and a smaller Compton radius. These two radii scale in a

[1]In general relativity, the exact equation is $dt/d\tau = (1 - 2Gm/c^2R)^{-1/2}$ and the weak gravity approximation is $dt/d\tau = (1 - Gm/c^2r)$. For an electron's mass and Compton radius, the weak gravity approximation is accurate to better than 1 part in 10^{40}.

way that keeps L_p exactly in the middle of the logarithmic length scale. A hypothetical particle with Planck mass would be the limit of wave-based particles because a particle with Planck mass would have its gravitational radius and its Compton radius both equal to L_p.

This article proposes that an electron's gravitational radius (~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. For example, the mass of all the electrons in the sun equals about 150 times the mass of the Earth. *It is possible to have a distortion of oscillating spacetime that is smaller than* L_p (~10^{-35} m), *even though it is not possible to have a wavelength smaller than* L_p (frequency > ω_p).

14. Electron's Gravitational Force Test

Next, we will develop further the concept that gravity is a wave-based nonlinear effect. The previous derivation of the electron's gravitational radius used only the strain amplitude (slope) of the rotating wave that forms the electron's core. The distortions of oscillating spacetime that create an electron's electromagnetic (EM) and gravitational fields are outside the electron's Compton radius (outside the mathematical radius). To analyze an electron's gravity, we will now assume two wave-based electrons separated by a distance larger than an electron's Compton radius ($r > r_c$). The test will be whether the wave-based model generates the correct gravitational force magnitude between two electrons.

Beyond the core ($r > r_c$), the model has rotating standing waves that decrease in amplitude with ($1/r$). The dimensionless *nonlinear* strain amplitude external to the core (designated $\mathcal{A}_G$) must equal the square of the nonlinear strain amplitude ($\mathcal{A}_G = L_p^2/r_c^2 = \mathcal{A}_e^2$) at distance $r = r_c$. Outside the core, there is a $1/r$ decrease in amplitude. We accomplish both goals if we designate the distance between the two electrons using the dimensionless number (N) of Compton radii ($N \equiv r/r_c = rm_ec/\hbar$). The gravitational strain amplitude (slope) then is ($\mathcal{A}_G = \mathcal{A}_e^2/N$) at a distance of N Compton radii from the electron's center.

Figure 6 shows an electron core centered on zero. This rotating wave structure includes a rotating standing wave "cloud" that extends indefinitely. Figure 6 shows a second rotating electron core on the right. This also has rotating standing waves, but these are not shown. Figure 6 illustrates the wave scale number $N = r/r_c$. An electron's natural unit of distance measurement is the number of Compton radii (r_c) separating two electrons. The second electron core in Figure 6 is rotating in the distorted volume of oscillating spacetime created by the central electron's standing waves. The separation between the two electron cores in Figure 6 is $N = 8\pi \approx 25$.

Moving forward, we will proceed with testing this hypothesis. Can we generate the gravitational force magnitude between two electrons using these properties and the properties of oscillating spacetime? The equation $F = kA^2\omega^2 Za/c$ gives the force (F) exerted on area (a) by a wave with amplitude (A) and frequency

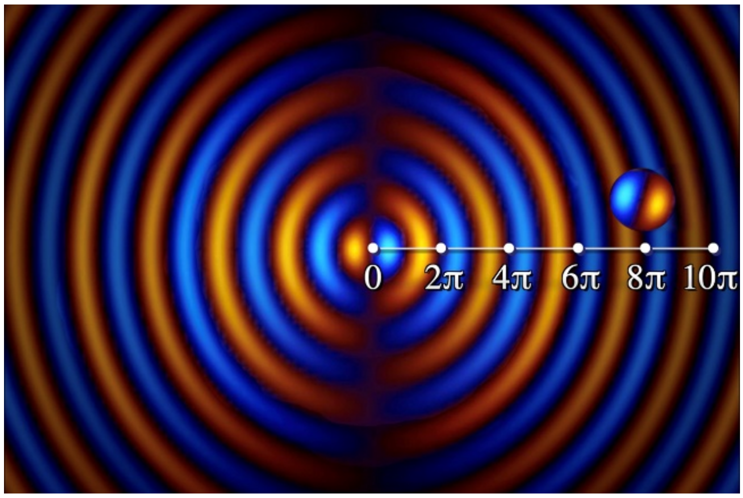

Figure 6. This shows the center electron's standing waves overlapping a second electron's core (on right). The white dots are separated by one complete Compton wavelength or 2π Compton radii ($2\pi r_c$). Therefore, the separation between the two electron cores in **Figure 6** is $N = 8\pi \approx 25$.

ω in a medium with impedance (Z) and propagation speed c. The unknown numerical constant near 1 is (k).

The simplified calculation assumes waves being continuously emitted by the central electron. A small part of these waves would strike the second electron's core area of ($a = kr_c^2$). This would produce a repulsive force (F_{Ge}). We will calculate the force magnitude using this model. If it gives the correct gravitational force magnitude, then the refined model will be discussed. For this initial calculation, the gravitational strain amplitude at separation distance of N Compton radii is: $\mathcal{A}_G = \mathcal{A}_e^2 / N$. Other substitutions into $F = kA^2\omega^2 Za/c$ are: $\omega = \omega_c = c/r_c$, area $= a = kr_c^2$, $Z_s = c^3/G$, and $N = r/r_c$ results in

$$F_{Ge} = \frac{k\mathcal{A}_G^2\omega_c^2 Z_s a}{c} = k\left(\frac{\mathcal{A}_e^2}{N}\right)^2 \frac{c^2}{r_c^2}\frac{c^3}{G}\frac{r_c^2}{c} = k\frac{\mathcal{A}_e^4}{N^2}F_p . \tag{15}$$

If we set $k = 1$, then Equation (15) becomes: $F_{Ge} = \left(\mathcal{A}_e^4 / N^2\right)F_p = Gm_e^2/r^2$. Success! No experiment is required. The starting point was the insight that oscillating spacetime should be a nonlinear medium that is unable to propagate waves with frequency greater than ω_p. This boundary creates the nonlinear amplitude $\mathcal{A}_G$ in Equation (15). This converts to Newton's gravitational equation for the gravitational force magnitude between two particles with an electron's mass (m_e). This is believed to be the first time a gravitational force magnitude has been derived in a bottom-up calculation of the quantum mechanical properties of particles. Before commenting further on this significant advance, we will first develop the electrostatic force between two electrons using the same electron model and the properties of oscillating spacetime.

15. Electron's Electrostatic Force Test

We will now proceed to use similar logic in an attempt to derive the magnitude of the electrostatic force between two electrons. The same force equation ($F = kA^2\omega^2 Za/c$) will be used. The only difference compared to the gravitational calculation Equation (15) is the following calculations will test two slightly different first order (linear) strain amplitudes. First: $A = (\mathcal{A}_e/N)$ and second $A = \alpha^{1/2}(\mathcal{A}_e/N)$. The symbol F_{qp} is the electrostatic force (Coulomb's law) between two Planck charges and F_{qe} is the electrostatic force magnitude between two electrons with charge e. Other substitutions are $\omega = \omega_c = c/r_c$; $Z = Z_s = c^3/G$ and area = $a = kr_c^2$ which leads to

$$F_{qp} = \frac{kA^2\omega^2 \mathcal{Z}a}{c} = k\left(\frac{\mathcal{A}_e}{N}\right)^2 \frac{c^2}{r_c^2}\frac{c^3}{G}\frac{r_c^2}{c} = k\frac{\mathcal{A}_e^2}{N^2}F_p \text{, and} \tag{16}$$

$$F_{qe} = \frac{kA^2\omega^2 \mathcal{Z}a}{c} = k\left(\frac{\sqrt{\alpha}\mathcal{A}_e}{N}\right)^2 \frac{c^2}{r_c^2}\frac{c^3}{G}\frac{r_c^2}{c} = k\frac{\alpha\mathcal{A}_e^2}{N^2}F_p . \tag{17}$$

If we set $k = 1$, Equation (16) becomes: $F_{qp} = \left(\mathcal{A}_e^2/N^2\right)F_p$. This converts to Coulomb's law for the force between two Planck charges ($F_{qp} = q_p^2/4\pi\varepsilon_0 r^2$). It was hoped that Equation (16) would generate the electrostatic force between two electrons. Instead, it generates the force between the two most fundamental units of charge (Planck charge q_p). The electron model is attempting to generate Planck charge. If 100% of the core energy is radiated, it would create Planck charge. However, vacuum polarization apparently reduces q_p by a factor of $\alpha^{1/2} \approx 0.085$ to charge e. The nonlinear wave component that creates gravity is unaffected by vacuum polarization. Therefore, vacuum polarization creates a difference of factor of $\alpha^{1/2}$ between the first order waves that create an electron's EM properties and the second order waves that create an electron's gravity.

Planck charge is the most fundamental unit of charge. It not only is derived by setting fundamental constants equal to 1, but two Planck charges have the maximum possible coupling constant equal to 1 because $q^2/4\pi\varepsilon_0\hbar c = 1$. For comparison, charge e has a coupling constant of α because $e^2/4\pi\varepsilon_0\hbar c = \alpha$.

The wave-based model of an electron is attempting to generate Planck charge because an initial wave amplitude of L_p at the base of the rotating standing waves would create Planck charge. However, if an electron had Planck charge, all of an electron's energy would be in the electric/magnetic field external to the electron's r_c. This would be unstable because there would be no energy in the electron's essential rotating core. Without vacuum polarization reducing the first order wave amplitude at the edge of the core from L_p to $\alpha^{1/2}L_p$, the stable electron would not exist. Mathematically, it is easy to accommodate this $\alpha^{1/2}$ reduction in standing wave amplitude. This is done by manually inserting ($\alpha^{1/2}$) into Equation (16) to generate Equation (17).

The force between two electrons, each possessing a charge of e, is denoted as F_e in Equation (17). To achieve this charge e force, Equation (16) uses the substitution $A = (\alpha^{1/2}\mathcal{A}_e/N)$. This generates $F_e = \left(\alpha\mathcal{A}_e^2/N^2\right)F_p = e^2/4\pi\varepsilon_0 r^2$. This is Coulomb's law for the electrostatic force between two electrons. Planck charge is: $q_p = (4\pi\varepsilon_0\hbar c)^{1/2} = 1.87 \times 10^{-18}$ coulomb. An electron's charge e is about 8.5%

of Planck charge ($e = \alpha^{1/2} q_p$). This addition ($\alpha^{1/2}$) reflects the structural modification nature requires to achieve the stable resonance condition that forms an electron. This $\alpha^{1/2}$ modification should have an unknown effect on the size and distribution of the electron's core.

In **Table 1**, the information in Equations (15)-(17) is presented in different ways that makes it easier to see that the electrostatic and gravitational forces between two electrons are closely related.

Table 1. The objective of this table is to prove the gravitational and electrostatic force magnitudes between two electrons are mathematically closely related. All the equations in Row 1 are equivalent to Newton's gravitational equation for an electron's mass m_e. All the equations in Rows 2 are Coulomb's law for two electrons. Row 3 is Coulomb's law for two Planck charges (q_p). A brief definition of some terms is in the footnote[a].

	Column 1 Introductory force equations using terms F_G, F_e and F_{qp}		Column 2 Force equations using Planck force F_p and Planck distance r/L_p		Column 3 Force equations using the wave properties $\mathcal{A}_e$ and N	
Row 1 F_{Ge}	$F_{Ge} \equiv \frac{Gm_e^2}{r^2}$	(18)	$F_{Ge} = \mathcal{A}_e^2 \frac{L_p^2}{r^2} F_p$	(21)	$F_{Ge} = \frac{\mathcal{A}_e^4}{N_e^2} F_p$	(24)
Row 2 F_{qe}	$F_{qe} \equiv \frac{e^2}{4\pi\varepsilon_0 r^2}$	(19)	$F_{qe} = \alpha \frac{L_p^2}{r^2} F_p$	(22)	$F_{qe} = \alpha \frac{\mathcal{A}_e^2}{N_e^2} F_p$	(25)
Row 3 F_{qp}	$F_{qp} \equiv \frac{q_p^2}{4\pi\varepsilon_0 r^2}$	(20)	$F_{qp} = \frac{L_p^2}{r^2} F_p$	(23)	$F_{qp} = \frac{\mathcal{A}_e^2}{N_e^2} F_p$	(26)

[a] $\mathcal{A}_e \equiv L_p/r_c = m_e/m_p = E_e/E_p = \omega_e/\omega_p = \left(Gm_e^2/\hbar c\right)^{1/2} = 4.18\times10^{-23}$ This dimensionless number is an electron's "structural constant". All of an electron's non-EM structural properties can be expressed in natural units with this number. F_{Ge} = the gravitational force magnitude between two electrons; F_{qe} = the electrostatic force magnitude between two electrons (charge e); F_{qp} = the electrostatic force magnitude between two Planck charges (q_p); Other terms are defined in Section 3.

Equation (18) is the Newtonian gravitational equation for two electron masses (m_e). Equation (19) is Coulomb's law for two electrons with charge e. Equation (20) is Coulomb's law for two hypothetical particles with Planck charge (q_p). These standard equations are included for easy comparison to other equations in **Table 1**.

Column 2 converts the three standard force equations in Column 1 to force equations incorporating Planck force $F_p = c^4/G = 1.2 \times 10^{44}$ N and dimensionless distance r/L_p measured in Planck units.

The equations in column 2 made a partial conversion to the wave properties of the electron by incorporating the wave's strain amplitude L_p/r at distance r. However, distance r is designated in meters, and meters are a length standard devised by humans. The model is predicting the electron's natural standard of length is its Compton radius ($r_c = 3.86 \times 10^{-13}$ m). If we want to fully convert the force equations to wave properties, (illustrated in **Figure 6**), we should designate the distance between two electrons as N Compton wavelengths ($N \equiv r/r_c$). The other wave property used in column 3 is an electron's strain amplitude $\mathcal{A}_e$. It specifies the strain amplitude of the core wave $\mathcal{A}_e = L_p/r_c = 4.18 \times 10^{-23}$. Column 3 shows the maximum mathematical unification between the gravitational and electrostatic force magnitudes because this column incorporates the most wave properties.

We will start by comparing the gravitational force magnitude Equation (24) to the Planck charge electrostatic force magnitude, Equation (26). The only difference between these two equations is the gravitational equation has $\mathcal{A}_e^4$ and the Planck charge electrostatic force equation has $\mathcal{A}_e^2$. Therefore, the difference (ratio) between these two forces is $F_{Ge}/F_{qp} = \mathcal{A}_e^2 = 1.75\times10^{-45}$. Equation (25) gives the electrostatic force between two electrons with charge e rather than charge q_p. Equation (25) requires the additional term α to accommodate the reduced electric field energy. Therefore, the force ratio is $F_{Ge}/F_{qe} = \mathcal{A}_e^2/\alpha = 2.4\times10^{-43}$. This is a simplification compared to the conventional ratio of $F_{Ge}/F_{qe} = Gm_e^2 4\pi\varepsilon_0/e^2 \approx 2.4\times10^{-43}$. The electron's constant $\mathcal{A}_e$ can be used to quantify all of a wave-based electron's non-EM structural properties.

16. What is Electric Charge?

From this analysis, it is now possible to understand another mystery of physics. Electrons and muons are currently visualized as charged point particles that are excitations in the electron and muon fields respectively. Electrostatic forces are currently visualized as virtual photon fluctuations in the EM field. According to this commonly held model, an electron, and a muon both have charge e because they both emit the same virtual photon fluctuations in the EM field. The EM force between two electrons is currently understood to be the exchange of virtual photons between charged particles. A muon's mass is about 207 times larger than an electron's mass. The gravitational force between two muons is $(207)^2 \approx$ 43,000 times larger than the gravitational force between two electrons. However, the electrostatic force is the same between two electrons or two muons. Therefore, charge is treated as an unexplained fundamental property, independent of mass. This results in the concept that the EM and gravitational forces are completely separate.

In the simplified model proposed here, the cores of an electron and a muon are both rotating soliton waves with the same displacement amplitude (L_p). The obvious differences are that a muon has more energy because it has 207 times higher rotational frequency and 207 times smaller Compton radius than an electron. However, there is also a more subtle difference between an electron and a muon. The model predicts a muon, and an electron should both have the same percentage of their energy in their respective electric fields (external to their cores). This implies a muon should have 207 times more energy in its electric field than an electron. This last statement seems impossible because they both have the charge e. Is this a fatal flaw in the model? No! This will be shown to be a reasonable prediction that actually supports the model.

The electric field energy is defined as the first order rotating standing wave energy external to their respective Compton radii. A muon's Compton radius is 1.86×10^{-15} m. An electron's Compton radius is 207 times larger ($3.86\times$

10^{-13} m). The muon's extra electric field energy is all packed into the small spherical shell volume with an inner radius of 1.86×10^{-15} m and outer radius of 3.86×10^{-13} m. Therefore, the muon *does* have 207 times more energy in its electric field than an electron. We only measure charge and electrostatic force at distance greater than 3.86×10^{-13} m. Therefore, we do not detect any difference between the electric field of a muon and an electron. The prediction is reasonable.

This is a partial answer, but it does not give a conceptually understandable answer to how two electrons and two muons can exert the same electrostatic force. The deeper answer is that the property we call "charge" is a first order distortion of oscillating spacetime. The rotating waves that form an electron and the muon have different frequencies and radii, but these waves both have the same displacement amplitude equal to Planck length ($A_d = L_p$). This wave amplitude produces a volumetric distortion of oscillating spacetime. Inside the cores this distributed distortion is equivalent to a total volume approximately equaling the volume of a sphere with radius of L_p. However, the vacuum polarization that takes place at the edge of the core reduces the charge from Planck charge to charge *e*. (from L_p to: $\alpha^{1/2}L_p \approx 0.085L_p$). Therefore, all fermions and hadrons with elementary charge *e* produce the same magnitude of first order distortion. This type of distortion will be designated "charge radius r_q" For charge *e*, the charge radius is: $r_q = \alpha^{1/2}L_p = 1.38 \times 10^{-36}$ m and Planck charge q_p has $r_q = L_p = 1.62 \times 10^{-35}$ m.

The concept of charge radius can be extended to improve our understanding of the unit of coulomb in equations. If oscillating spacetime is the universal field, coulomb must be able to be converted to a property of spacetime. The model predicts that Planck charge produces a L_p polarized distortion of the oscillating spacetime field. Therefore, (L_p/q_p) is the proposed "charge conversion constant" that converts electrical charge, with unit of coulomb (C), to a distortion of spacetime with unit of meter. This is actually a unit of "polarized length" that incorporates a vector (discussed later). The following Equation (27) is the proposed "charge conversion constant L_p/q_p" that will be used to convert a unit of coulomb to a unit of polarized length

$$\frac{L_p}{q_p} = \sqrt{\frac{G}{4\pi\varepsilon_0 c^4}} = 8.617 \times 10^{-18}\ \text{m/C}. \tag{27}$$

The way L_p/q_p is used will be demonstrated using the Coulomb force constant $1/4\pi\varepsilon_0$. This has dimensional analysis units of ML^3/T^2Q^2. Therefore, we want to eliminate the Q^{-2} term (inverse coulomb squared). This is accomplished as follows: $(1/4\pi\varepsilon_0)(q_p/L_p)^2 = c^4/G$. Converting coulomb to meter using L_p/q_p, the Coulomb force constant converts to Planck force (c^4/G). This is reasonable and gives a new insight.

Electrical current with unit of coulomb/second converts to m/s. Therefore, 1 ampere converts to 3.33×10^{-9} m/s and Planck current ($I_p = 3.48 \times 10^{25}$ amp) converts to the speed of light. Electrical potential (voltage) converts to a force.

For example, one volt converts to 1.16×10^{17} N. An electron, passing through a 1 volt drop, does not experience a force of 1.16×10^{17} N. Instead, an electron's distortion of spacetime ($\alpha^{1/2}L_p = 1.38 \times 10^{-36}$ m) encounters a force of 1.16×10^{17} N. Force times distance equals energy. Therefore, 1.16×10^{17} N $\times$ 1.38×10^{-36} m $= 1.6 \times 10^{-19}$ J = 1 eV. This indeed is the energy gained by an electron passing through a 1-volt electrical potential. Equation (28) shows that the impedance of free space ($Z_0 = 1/\varepsilon_0 c \approx 377\ \Omega$) encountered by photons converts to the impedance of spacetime c^3/G because

$$Z_0\left(\frac{q_p}{L_p}\right)^2 = \left(\frac{1}{\varepsilon_0 c}\right)\left(\frac{4\pi\varepsilon_0 c^4}{G}\right) = 4\pi\frac{c^3}{G}. \tag{28}$$

The 4π can be ignored in Equation (28). Proving that Z_0 converts to c^3/G is important because this says that photons propagate in the medium of oscillating spacetime. Recall that c^3/G was the calculated impedance of both oscillating spacetime, and the impedance encountered by GWs. Therefore, Equation (28) completes this concept and adds photons as quantized waves propagating in the universal field of oscillating spacetime. Terminal collapse gives the photon its particle-like properties.

The term "polarized length" implies it is a unit of length that has a vector. The charge conversion constant can only be used in electrical equations where the radial terms are aligned with the electrical field gradient. The charge conversion constant cannot be used to convert the magnetic field strength H (unit: C/sm) and the magnetic flux density B (unit: kg/sC). The reason for this appears to be that magnetic equations incorporate cross products that create vector conflicts with the polarized length property of the electrical charge.

The distortion of oscillating spacetime produced by electrical charge appears to be more complex than the distortion produced by gravity. For example, this model has not yet explained the structural difference between an electron and a positron. For example, the difference between positive and negative charge perhaps requires a phase distortion at the level of ω_p. This is one of many challenges remaining before this wave-based model of the universe matures.

17. Unification of Forces at the Planck Limit

There is a thought experiment that *proves* that the gravitational and EM forces converge and produce the same force magnitude at the Planck particle limit. It will be shown that the gravitational force between two particles with Planck mass (m_p) equals the electrostatic force between two particles with Planck charge (q_p). This equality at the Planck particle limit clearly establishes the close connection between these forces. Before describing this thought experiment, it is useful to briefly describe Planck charge and Planck mass (m_p and q_p).

Planck charge ($q_p = (4\pi\varepsilon_0\hbar c)^{1/2} = 1.88 \times 10^{-18}$ C) is the natural unit of charge that results from setting $c = 1$, $\hbar = 1$ and setting the coulomb constant also equal to one ($1/4\pi\varepsilon_0 = 1$). However, Planck charge is more than just a unit of charge derived from fundamental constants. Planck charge implies the theoretical maximum charge radius equal to Planck length ($r_q = L_p$). In the wave-based model, Planck charge would result if 100% of the particle's energy was in its electric/magnetic field. This limiting case would be unstable because no energy would be in the essential core. Charge e is a factor of $\alpha^{1/2} \approx 8.5\%$ of Planck charge ($e = \alpha^{1/2} q_p$). Two hypothetical particles with Planck charge would repel each other with a force about 137 times larger than the electrostatic repulsive force between two electrons.

Planck mass ($m_p = (\hbar c/G)^{1/2} = 2.18 \times 10^{-8}$ kg) is the maximum possible mass/energy a single fermion can have. A wave-based particle with Planck mass/energy would have a Compton radius equal to L_p. Therefore, a Planck mass particle would have the maximum possible nonlinear strain amplitude of nonlinear strain amplitude ($\mathcal{A}_G = L_p^2/r_c^2 = L_p/L_p = 1$). A hypothetical particle with Planck charge would have the maximum possible displacement amplitude external to the core. Therefore, a Planck mass particle has similarities to a Planck charge particle because they both represent the limits of particle properties. The related force equations are

$$F_{Gp} = \frac{Gm_p^2}{r^2} = \frac{G}{r^2}\frac{\hbar c}{G} = \frac{\hbar c}{r^2}, \tag{29}$$

$$F_{qp} = \frac{q_p^2}{4\pi\varepsilon_0 r^2} = \frac{4\pi\varepsilon_0 \hbar c}{4\pi\varepsilon_0 r^2} = \frac{\hbar c}{r^2}, \tag{30}$$

$$F_{Gp} = F_{qp} = \hbar c/r^2 . \tag{31}$$

Equation (29) calculates the gravitational force (F_{Gp}) between two hypothetical particles with Planck mass (m_p) and Equation (30) calculates the electrostatic force (F_{qp}) between two hypothetical particles with Planck charge (q_p). The amazing result is that at arbitrary separation distance (r), *they both generate the same force magnitude*. These forces have opposite vectors, but the same force magnitude. This is summarized in Equation (31). The equality of forces at the Planck limit of mass and charge was predicted by the wave-based model because the distinction between first and second order effects disappear at this Planck limit. This concept will be explained by comparing the electrostatic Equation (23) for two Planck charges (q_p), to gravitational Equation (21) for arbitrary mass. The only difference is that gravitational Equation (21) contains strain amplitude squared ($\mathcal{A}_s^2 = L_p^2/r_c^2$) and Equation (23) does not. For Planck mass, the Compton radius equals Planck length ($r_c = L_p$). Therefore, for Planck mass the strain amplitude equals 1 because ($\mathcal{A}_s^2 = L_p^2/r_c^2 = 1$). Therefore, the enormous difference between the gravitational and electrostatic forces disappears at the Planck limit. Below, Equation (32) extends Equation (29) to cover two particles with the same arbitrary mass (m) and Equation (33) extends Equation (30) to cover two particles with the same arbitrary charge (q)

$$F_{\mathrm{G}} = \left(\frac{m}{m_{\mathrm{p}}}\right)^2 \frac{\hbar c}{r^2}, \tag{32}$$

$$F_{\mathrm{q}} = \left(\frac{q}{q_{\mathrm{p}}}\right)^2 \frac{\hbar c}{r^2}. \tag{33}$$

By dividing arbitrary mass (m) by Planck mass (m_{p}), we have a scaling factor (m/m_{p}) that references m_{p}. Equation (32) converts to ($F_{\mathrm{G}} = Gm^2/r^2$), the Newtonian gravitational law equation for two of the same masses (m). Equation (33) is similar, but it gives the electrostatic force (F_{q}) between two particles with the same charge q. Equation (33) converts to ($F_{\mathrm{q}} = q^2/4\pi\varepsilon_0 r^2$). This is the Coulomb law equation for the electrostatic force between two particles with charge (q).

There is another type of unification of forces that occurs when two particles are assumed to be separated by a distance equal to their Compton radius. We will compare the gravitational and electrostatic forces between two hypothetical particles with an electron's mass and Planck charge. The force magnitude between these particles will be expressed in dimensionless Planck units. Therefore, we will define $\mathcal{F}_{\mathrm{Ge}} \equiv F_{\mathrm{Ge}}/F_{\mathrm{p}}$ and $\mathcal{F}_{qp} \equiv F_{\mathrm{qp}}/F_{\mathrm{p}}$. The relationship is

$$\mathcal{F}_{\mathrm{Ge}} = \mathcal{F}_{\mathrm{qp}}^2 = \mathcal{A}_{\mathrm{e}}^4 = \left(4.18\times10^{-23}\right)^4. \tag{34}$$

At this separation, the *square* of the electrostatic force equals the gravitational force. These dimensionless numbers also equal the electron's strain amplitude raised to the 4th power ($\mathcal{A}_{\mathrm{e}}^4$). These relationships are easily derived by setting $N = 1$ in Equations (24) and (26).

These connections between the gravitational and EM forces do not conflict with the mathematical equations of general relativity or electromagnetism. The connections only conflict with the common physical interpretation that the EM force is conveyed by the exchange of messenger particles and gravity is a pseudo force created by the geometric curvature. These physical interpretations cannot explain the various unifications of forces described in this article.

However, in the wave-based model, gravity and the EM force are both conveyed through related distortions of the universal field (oscillating spacetime). Therefore, the $F_{\mathrm{G}}/F_{\mathrm{e}}$ ratio of these two forces between two electrons can be expressed simply as the ratio of distortions. $F_{\mathrm{G}}/F_{\mathrm{e}} = \mathcal{A}_{\mathrm{s}}^2/\alpha = 2.40\times10^{-43}$. The gravitational force is an obvious curvature of spacetime. The other three forces are less obvious distortions of oscillating spacetime. For example, electromagnetism might be a subtle phase shift of the Planck frequency oscillations present in oscillating spacetime. This is a subject for future study.

18. How Big is an Electron?

The simplified electron model previously discussed is suitable for the various tests associated with calculating the properties of the wave-based electron model. However, an electron is a quantized wave that can easily change its size and shape. Therefore, the electron model needs to be expanded to accommodate the ability of an electron to change its size and shape.

This question about the size of an electron can be answered on three different levels. The first level is to visualize the traditional concept of an electron that has a central particle surrounded by an electric/magnetic field. Even with this description, the wave-based model differs with the traditional concept of an electron's size because the wave-based model includes the electron's electric field as part of the electron's structure. **Figure 5(C)** shows a rotating wave surrounding the central core. This external rotating standing wave is the part of the electron's structure that creates an electron's electric/magnetic field. The energy in the electron's electric field contributes to the electron's total energy. For example, the energy in an electron's electric field external to radial distance r is: $E_{ext} = e^2/4\pi\varepsilon_0 r = \alpha\hbar c/r$. Even with a large value of r, this energy never goes to zero. For example, the energy in the electron's electric field beyond the Bohr radius of a hydrogen atom (~5×10^{-11} m) is 13.6 eV. The wave-based model of an electron shown in **Figure 5(C)** shows the extended electron model.

An electron's mass/energy has been experimentally measured to an accuracy of 1.1×10^{-38} kg $\approx 10^{-21}$ J [35]. This means using $E_{ext} = \alpha\hbar c/r$, the electron's experimentally measurable energy includes the contribution of an electron's electric field energy out to a radius of about 2×10^{-7} m. This is more than 10^{11} times larger radius than 10^{-18} m. However, there is no limit to the extent of an isolated electron's electric field. *We should say an electron is the opposite of a point particle—it is indefinitely large*. We ignore the electron's distributed energy and wave properties when we search for a nonexistent central particle.

The second level of answer to this question considers an electron bound in an atom. The positive charge of the nucleus limits the extent of an electron's negative electric field. For example, an electron in a hydrogen atom has different wave functions associated with different orbitals. These wave functions can exceed 10^{-10} m in radius. This is much larger than the electron's Compton radius (3.86×10^{-13} m) previously discussed in the simplified electron model. If an electron is confined in some way, then the electron's wave structure adjusts to achieve the distribution of the electron's wave function determined by the Schrodinger equation.

An electron in a hydrogen atom encounters the positive electric field of the nucleus. This creates a distributed, soft boundary for the electron. The single Compton frequency of the simplified electron model is replaced by the multiple frequency wave components of an electron confined to a hydrogen atom. These different frequencies are close to the electron's ω_c but constructive and destructive interference between the slightly different frequencies create the moving modulation envelopes that result in the orbital shapes described by the Schrodinger equation. These are distributed wave effects rather than the probability distribution of a moving point excitation.

The third way of describing an electron's size ultimately explains how an electron acquires its particle-like properties. We will start this explanation with the wave function of a particle-in-a-box. The Schrodinger equation allows the calculation of the wave function of a hypothetical particle in a one-dimensional box with impenetrable boundaries. The wave function is usually considered to be a mathematical description of the quantum state of an isolated particle. Squaring the wave function turns the complex probability amplitude into an actual probability. The wave-based model considers the wave function to be a representation of an actual quantum mechanical wave distortion of oscillating spacetime. For example, an electron, confined in a Penning trap, has a quantifiable wave function within this device. In the wave-based model, the trapped electron is a physical quantized soliton wave in oscillating spacetime. Squaring the wave function gives the intensity of the wave. This intensity corresponds to the probability of the location where the distributed wave is likely to collapse into the compact form that can be observed (an observable electron).

Now we come to the important question. How does the wave-based model convert the widely distributed quantized wave represented by the electron's wave function, into an observable electron particle? The key to this transition is the electron's quantized angular momentum. All quantization in the universe is proposed to be ultimately traceable to angular momentum being quantized. Fermions have $\hbar/2$ angular momentum when measured along a single axis and photons have $\hbar$ angular momentum. In the wave-based model, when a widely distributed quantized wave is observed, there is a superluminal collapse from the distributed wave structure to a much smaller wave structure that has the properties of a particle with quantized angular momentum.

We know that two entangled particles can undergo superluminal adjustment when one of these is observed. Within a single quantized wave such as an electron, superluminal adjustments must also happen. The electron possesses a quantized unit of angular momentum. This quantized angular momentum *requires* that 100% of the quantized angular momentum in the widely distributed quantized wave must be preserved as a unit. The distributed wave, described by the wave function, undergoes a superluminal collapse to a much smaller size wave that retains 100% of the quantized angular momentum. The superluminal "collapse of the electron's distributed wave function" really happens when an electron is "observed". This will be designated as a superluminal "terminal collapse".

To give an extreme example, we will switch from an electron to a single photon confined in an optical resonator with 100% reflecting mirrors. Imagine we introduce several absorbing atoms into this optical resonator volume. It takes time for a photon to be absorbed [36]. Therefore, it is possible for several atoms to start to absorb the single photon simultaneously. However, the photon's $\hbar$ quantized angular momentum cannot be divided. This example requires that a partial absorption can be reversed so that 100% of the quantized angular momentum can be deposited into a single atom. The idea of reversal of a partial absorption seems unrealistic. However, this has already been experimentally observed! In the article in Nature titled *To catch and reverse a quantum jump mid-flight*, [37] Minev et al experimentally demonstrate that the jump from the ground to an excited state of a superconducting artificial three-level atom can be tracked and reversed. They say, "using real-time monitoring and feedback, we catch and reverse a quantum jump mid-flight, thus deterministically preventing its completion." [37] This is a demonstration of the power of quantization.

The ability to achieve a superluminal collapse is *required* to achieve the complete transfer of a photon's quantized angular momentum into a single atom. Even if a photon was starting to be absorbed by multiple other atoms, these partial interactions must be reversed. Quantized angular momentum demands that the photon's entire $\hbar$ angular momentum must be transferred into a single lucky atom. Usually, this requires a superluminal collapse. All the photon's energy is also transferred as a byproduct of the complete transfer of angular momentum.

There is one more question about an electron's size that needs to be addressed. How is it possible for an electron to probe the quark structure of a proton if the electron's mathematical radius (Compton radius) is $r_c = 3.86 \times 10^{-13}$ m? A wave-based electron's size can not only get larger when unbounded, but the size will also momentarily decrease to less than r_c in a collision. For example, in an ultra-relativistic collision, the kinetic energy of the collision is momentarily converted to an electron's internal energy. This additional energy increases the electron's rotational frequency, reduces its radius, and keeps the electron's angular momentum constant. In a collision with a 200 GeV proton, the electron's mathematical radius can momentarily be reduced to about 10^{-18} m. This explains how an electron can probe the much smaller proton's internal quark structure yet have a relatively large wave function volume in other experiments.

The electron has a wave structure that is undetectable. It is impossible to detect a L_p displacement of oscillating spacetime. Experiments such as the double slit experiment indicate that an electron has wave properties, but the waves themselves are undetectable. This quantized wave can shrink to less than 10^{-18} m or increase to indefinitely large. Therefore, visualizing this as a corpuscular particle or even a point-like excitation of a field creates numerous mysteries. The wave-based model solves most of these mysteries.

19. Photon Model

In the late 19th century and early 20th century, there was nearly universal acceptance that light was a wave that propagates in the luminiferous aether. The Michelson-Morley experiment, the photo-electric effect and Compton scattering experiment all seemed to require that a photon was a quantum mechanical particle that did not require a propagation medium. Since the luminiferous aether was not observable, the aether was declared "superfluous" and abandoned. This article proposes that oscillating spacetime fulfills the functions of all the 17 fields of quantum field theory. Therefore, all 17 separate fields are proposed to be superfluous. Eliminating 17 overlapping fields and replacing them with a single universal field (oscillating spacetime) achieves the simplification supported by Occam's razor.

A photon is modeled as a quantized wave in oscillating spacetime. The quantization occurs because each photon has $\hbar$ quantized angular momentum. Even a large wave with $\hbar$ angular momentum is quarantined as it propagates through the superfluid oscillating spacetime. The photon's particle-like properties only appear when the photon undergoes a terminal collapse. There is no particle component or particle-like excitation in this model of a photon. The following two thought experiments demonstrate that a photon cannot be a point excitation of the EM field or have any other particle-like property.

The first thought experiment incorporates lasers that are extremely monochromatic. Lasers are routinely stabilized to achieve a bandwidth of about 1 Hz. The most stable lasers have achieved a bandwidth of 0.01 Hz [38]. A laser with a spectral bandwidth of 0.01 Hz is almost perfectly monochromatic. Photons with 0.01 Hz bandwidth must be a perfect sine wave over a time period of at least 100 seconds. Therefore, each photon with 0.01 Hz bandwidth must be at least 3×10^{10} m long. This is more than 75 times the 3.84×10^{8} m distance between the Earth and the moon! This monochromatic wave can also be spherically diverging and be spread over an enormous volume. The idea of a particle-like single excitation making discontinuous jumps (superluminal jumps) over a diverging beam with 3×10^{10} m length to create a photon's wave properties is ridiculous. The alternative wave-based model of a photon has no particle component (no point excitation). All the photon's particle-like properties are achieved by a superluminal terminal collapse when the widely distributed wave-based photon is absorbed. If the photon's widely distributed waves encounter a non-absorbing object, the modified wave pattern undergoes a superluminal adjustment of the distributed wave that preserves all the photon's angular momentum and energy.

The second thought experiment uses a Michelson interferometer with the two arms that are unequal lengths. For example, suppose that one arm is 1500 meters longer than the other. The light that makes the round trip in this arm is delayed by 10 microseconds and 3000 meters compared to the light that goes down the shorter arm. The two reflected beams are then combined in the usual 50% reflecting beam splitter used in a Michelson interferometer. Therefore, if the laser providing the input beam to this interferometer has a coherence length less than 3000 meters, (bandwidth greater than 100 kHz), then the two beams will combine incoherently at the output beam splitter. However, if a stable laser with a bandwidth much less than 100 kHz is used (e.g. 1 Hz bandwidth), the beams will combine coherently at the output beam splitter. It will be possible to achieve destructive interference in one output direction and constructive interference in the other output direction even with a large unequal path length. If there is a large optical path length difference between the two arms, the particle or point excitation model of a photon becomes unworkable.

Laser radar systems that utilize heterodyne detection are essentially interferometers with unequal arm lengths. A beam splitter generates two beams. One beam is sent to a distant target and the very weak reflection is returned to the interferometer where it is mixed in a beam splitter with the other beam (the local oscillator beam) that has traveled a much shorter distance. I was a co-inventor and part of a small team that experimentally demonstrated the feasibility of such a heterodyne detection laser radar system. The laser radar apparatus is described in the patent [39]. The difference between the two optical path lengths in the laser radar system exceeded 3 km. The CO_2 laser used had a narrow bandwidth that met the theoretical stability requirement.

The usual answer is to merely say that the photon's particle properties only occur when the photon is observed. However, that describes the properties of the proposed wave-based model of a photon. This quantized photon wave only gains its particle-like properties when it undergoes a superluminal terminal collapse when it is detected. There is no point excitation in a hypothetical background EM field. The description of the photon model is further clarified in the next section dealing with entanglement.

20. Wave-Based Explanation of Entanglement

We can also test the concept of terminal collapse to see if it explains the many counterintuitive properties of entanglement. Here is the concept. Two photons that share a single quantum state are said to be entangled. Entanglement experiments that use linear polarizers will be used in this explanation. If one entangled photon is detected after it passes through a linear polarizer with a particular orientation, the other entangled photon instantly achieves the orthogonal liner polarization. This presents the following three mysteries: 1) How do the two entangled photons achieve superluminal communication? 2) How are the two separated photons able to keep track of each other? 3) How does one entangled photon convey the exact polarization angle information to its entangled partner?

This explanation will use the annihilation of an electron-positron pair to generate two entangled photons. This exotic example is used because it avoids the complexities of the more conventional ways of generating two entangled photons. **Figure 7** shows a central point that was the location of the electron-positron annihilation. The wave-based model does not produce two, point particle photons propagating in opposite directions. Instead, **Figure 7** shows that the two entangled photons are represented by a spherical shell of waves propagating away from the annihilation point. In this form, these two entangled waves have not yet chosen their momentum vectors and polarization directions. **Figure 7** shows the concentric waves just prior to the first of the two entangled photons undergoing a superluminal terminal collapse into the absorbing particle at the bottom of **Figure 7**. This collapse extracts the wave amplitude distribution of the first photon. This distribution is given by the Kirchhoff obliquity factor $K(\theta) = \cos^2(\theta/2)$, explained in [40]. Reference [41] gives more details about a photon's amplitude and predicted intensity limitations.

Figure 8 shows the amplitude distribution of the remaining concentric waves after the first photon's waves have been extracted. The collapse of the first photon's waves deposited a specific momentum vector and polarization into the absorbing particle near the bottom of **Figure 8**. The amplitude of the remaining waves is represented by the gray scale in Figure 8. These waves have zero amplitude (white color) near the absorbing particle because the first photon extracted the maximum wave amplitude there. The remaining waves have maximum amplitude (black color) at the top of Figure 8 because the remaining photon has maximum amplitude in this direction. This distribution creates the momentum direction and uncertainty angle for the remaining waves. This wave distribution will also undergo a super luminal collapse when it is finally absorbed by a particle within the "momentum uncertainty angle".

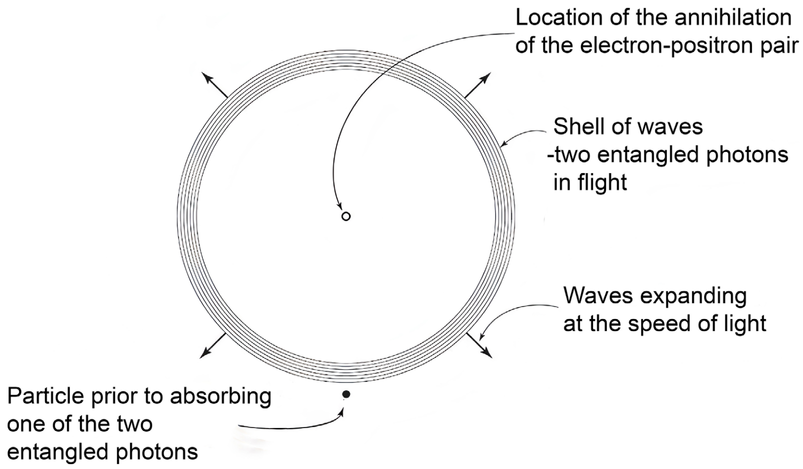

Figure 7. Two entangled photons created by the annihilation of an electron-positron pair are represented by concentric spherical waves that propagate in oscillating spacetime.

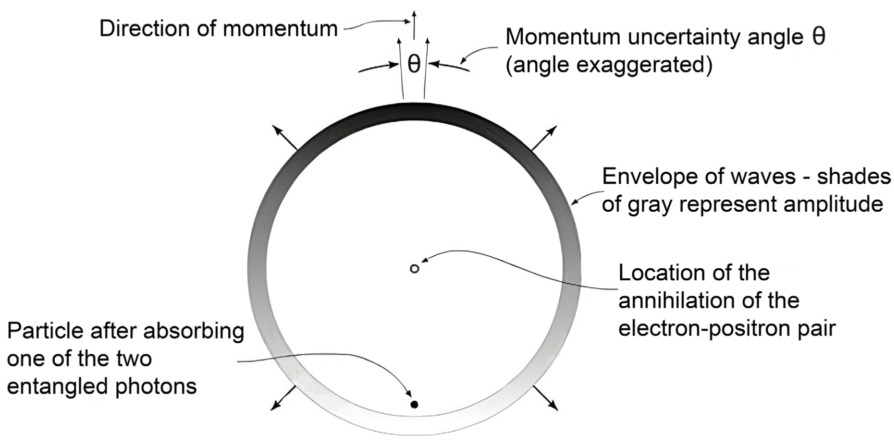

Figure 8. The shades of gray represent the amplitude distribution of the remaining waves after the first wave-based photon has been extracted. These remaining waves form the second of the two entangled photons.

This model conceptually explains the three mysteries of entanglement previously enumerated. 1) There is no superluminal communication between the two entangled photons. The first of the two entangled photons to be observed merely undergoes a superluminal collapse into the absorbing particle. This withdraws the waves needed to achieve the first photon's polarization and momentum. 2) The two entangled photons do not need a mysterious way of keeping track of each other. The distributed cloud of waves can generate any polarization for the first photon. Once this polarization and momentum is extracted from the wave function, the remaining waves automatically have the orthogonal polarization and orthogonal momentum vector. 3) There is no need to have superluminal communication of information between entangled partners, which is also explained in point #2. The wave-based model of entanglement is conceptually understandable.

21. Falsifiable Predictions

This section gives two additional falsifiable predictions that are logical extensions of the oscillating spacetime model. Previous predictions such as the electron's gravitational radius ($r_G = L_p^2 / r_c$) and the merging of the gravitational and electrostatic force magnitudes at the $L_p - q_p$ limit are mathematically proven ($F_{Gp} = F_{qp} = \hbar c/r^2$). Therefore, they do not qualify as falsifiable predictions that need further proof. However, the following predictions are uncertain and therefore qualify as falsifiable.

The first falsifiable prediction is: The physical laws are not the same in *all* inertial frames of reference. One of the starting postulates used by Einstein to develop special relativity was: The physical laws are the same in all inertial frames of reference. This postulate is universally accepted. There have been no confirmed experiments that disprove this postulate. However, this postulate has not been tested in ultra relativistic frames of reference addressed here. The articles that examined the sonic universe hypothesis [10]-[12] mathematically proved that it is not possible to observe motion relative to the privileged rest frame of the assumed sonic medium. However, the sonic medium assumed by these references was overly simplified. There was no mention that a real sonic medium would have a boundary condition set by the finite maximum frequency the sonic medium can propagate. Oscillating spacetime cannot propagate waves with a frequency higher than ω_p or wavelength shorter than L_p in the privileged frame where the medium is stationary (the CMB rest frame). This is a boundary condition that leads to the following prediction: The physical laws are not the same in *all* inertial frames of reference.

To explain this shocking prediction, we will start with **Figure 3(A)**. This figure shows an electron's outward propagating waves viewed with relative motion equal to 25% the speed of light. For this explanation, we will assume the "stationary" frame of reference is the CMB rest frame. An electron moving relative to this privileged rest frame requires the medium to be capable of propagating frequencies both higher and lower than an electron's ω_c. For example, **Figure 3(A)** depicts a computer simulation, using Mathematica, of spherical waves viewed from a frame of reference with relative motion equal to 25% of the speed of light. These outward propagating waves, moving in the direction of travel, undergo a relativistic Doppler shift to about 28% higher than the Electron's Compton frequency. As shown in **Figure 3(A)**, this higher frequency produces a shorter wavelength in the direction of motion. Waves propagating in the opposite direction are redshifted to a longer wavelength. In the electron's rest frame, the standing waves have an electron's $\lambdabar_c$. However, an electron moving relative to the privileged frame requires the privileged frame medium to be able to support a shorter wavelength (higher frequency) than an electron's Compton wavelength/frequency. This becomes impossible for an electron in the most extreme, ultra relativistic frames of reference.

For an ultra-relativistic frame of reference, relative to the privileged CMB rest frame, the following approximation can be used: $\lambdabar_d \approx \lambdabar_c/\gamma$. For example, when $\gamma > \sim 10$, an electron's de Broglie wavelength ($\lambdabar_d$) is approximately equal to an electron's Compton wavelength ($\lambdabar_c$) divided by the Lorentz factor γ. To achieve an ultra-relativistic de Broglie wavelength $\lambdabar_d$, the privileged frame must be capable of propagating a wave with wavelength $\lambdabar = \lambdabar_d$.

Therefore, there are ultra relativistic frames of reference where wave-based electrons cannot exist because they would require wavelengths shorter than L_p in the privileged frame. For example, a frame of reference with a Lorentz factor of $\gamma > 2.4 \times 10^{22}$ would require waves shorter than L_p (frequencies higher than ω_p) in the privileged frame ($\lambdabar_c/2.4 \times 10^{22} = L_p$). Therefore, there are no electrons in frames of reference with $\gamma > 2.4 \times 10^{22}$ relative to the privileged frame (relative to the CMB rest frame). Protons and neutrons have de Broglie wave properties [42]. These more energetic particles have a lower cutoff γ than electrons. For example, the wave-based model predicts there are no protons or neutrons in frames of reference with $\gamma > 1.3 \times 10^{19}$ relative to the privileged frame (relative to the CMB rest frame). The physical laws would clearly be different in frames of reference that do not allow protons or neutrons. Therefore, the wave-based model predicts that the physical laws are not the same in *all* inertial frames of reference.

The second falsifiable prediction is: The Big Bang (BB) started as oscillating spacetime with Planck energy density $U_p \approx 10^{113}$ J/m^3. The wave-based model of the universe starts with the BB with the highest energy density oscillating spacetime can generate—U_p. This highest energy density ($\sim 10^{113}$ J/m^3) of *observable* energy density is modeled as Planck energy density of Planck energy photons. This starting condition is perfectly homogeneous. This starting condition will be designated "Planck spacetime" because all the properties of this spacetime equal 1 in natural Panck units. At 1 unit of Planck time ($t_p = 1 \approx 10^{-43}$ s), this medium has the following *observable* properties: Planck energy density ($U_p \approx 10^{113}$ J/m^3), Planck temperature ($\mathcal{T}_p \approx 10^{32}$ K) and Planck pressure ($\mathcal{P}_p \approx 10^{113}$ N/m^2). The only force is Planck force ($F_p \approx 10^{44}$ N). Each photon has Planck energy ($E_p \approx 2 \times 10^9$ J). These starting conditions all equal 1 in dimensionless Planck units.

This starting condition is perfectly homogeneous because it is the limiting maximum condition of spacetime. In the first unit of Planck time, each Planck energy photon is isolated. There is no gravity at $t_p = 1$ because there was no prior time for gravity to spread. The gravitational influence of each Planck volume begins to uniformly spread at $t_p = 2$ (the first running time unit in the age of the universe). This produces a nonlinear gravitational effect that results in an increase in volume and a decrease in energy density. This perfectly homogeneous starting condition is maintained as this model of the universe evolves to lower density and lower temperature. No inflationary phase is required to achieve homogeneity. The starting homogeneity is merely maintained as the universe changes with age.

One of the mysteries of the universe is designated as the "flatness problem" [43]-[45]. The Wilkinson Microwave Anisotropy Probe (WMAP) [2] determined the current density of the universe is within 1% of the critical density required to achieve flat space. Extrapolating back in time to the "Planck era" at the start of the BB (the first $\sim 10^{-43}$ s), the homogeneity of the universe must have matched the critical density to better than 1 part in about 10^{60} at the Planck era [43]-[45]. The currently accepted BB theory is a physical theory that describes how the universe started with an infinitely hot and dense single point that inflated and stretched. [43]. A high-density entity does not expand uniformly. It cannot achieve today's homogeneity and critical density. The inflationary BB explains neither the origin of the 17 fields required by quantum field theory nor a model of a sonic universe required to achieve Lorentz transformations (see Section 3). The alternative suggested here is to start the BB with Planck spacetime with all its properties equaling 1 in natural units. This is the ultimate simplicity. Furthermore, Planck spacetime evolves into the sonic universe we have today. Lorentz transformations, a universal field, and the constant speed of light are all logical results of starting the BB with Planck spacetime. An attempt to describe in more detail how Planck spacetime evolved into today's the wave-based universe is given in chapters 13 and 14 of reference [46]. This alternative model of the BB is in its infancy.

22. Summary and Conclusion

This article describes a model of the universe based on John Wheeler's proposal that spacetime is a medium that has Planck length oscillations, predominantly at Planck frequency. This article quantifies the properties of this medium and proposes that oscillating spacetime is the foundation of everything in the universe. Therefore, this single "universal field" holds the key to unifying all particles and forces. The multiple fields of quantum field theory are characterized as lower frequency resonances and properties of this Planck frequency oscillating medium.

There are no particles or point-like excitations in this model of the universe. Electrons and other fermions are modeled as rotating quantized waves in the medium of oscillating spacetime. An electron appears to have wave-particle duality even though it is fundamentally a quantized wave because each wave-based electron possesses a quantized unit of angular momentum. The article explains how a distributed quantized wave undergoes a superluminal "terminal collapse" when "observed" and achieves its particle-like properties.

This wave propagation medium has enormous impedance of $Z_s = c^3/G = 4 \times$

10^{35} kg/s. This gives the spacetime medium enormous stiffness and makes it possible for a rotating wave with undetectable L_p amplitude to generate the energy and gravity of any fermion or boson. This model of oscillating spacetime is successfully tested by seeing if it is theoretically possible to generate a plausible model of an electron from this medium. Tests of the wave-based electron model are shown to approximately generate an electron's energy, de Broglie waves, angular momentum, zitterbewegung, particle-like properties and variable sizes wave distributions. This soliton wave can momentarily be smaller than a proton in a high energy collision or can have a relatively large volume of an atom's orbital wave function.

This model predicts that oscillating spacetime is a nonlinear medium. Waves in this medium have both a linear component and a much weaker nonlinear component. Analysis of the electron model shows that the electron's EM properties are derived from the linear component and the electron's gravitational properties are derived from the nonlinear component. These forces are predicted to be related because they are similar distortions of oscillating spacetime. This insight leads to the prediction that the gravitational force between two Planck masses should equal the electrostatic force between two Planck charges. This prediction is shown to be correct. Both force magnitudes equal $\hbar c/r^2$. Furthermore, the electron's quantum mechanical wave properties are shown to generate an electron's gravitational radius ($r_G = L_p^2 / r_c = 6.76 \times 10^{-58}$ m) and an electron's charge radius ($r_q = \alpha^{1/2} L_p = 1.38 \times 10^{-36}$ m).

Conclusion: The proposed wave-based model of the universe is both plausible and useful. This model simplifies all of physics because everything in the universe is derived from a single wave propagation medium (oscillating spacetime). It is easy to calculate the predicted properties of this model because the model incorporates quantifiable waves in a quantifiable medium. This model is also useful for education because quantum mechanical properties that are counter intuitive when visualized as particles are conceptually understandable when visualized as quantized waves.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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