Spacetime Based Foundation of Quantum Mechanics and General Relativity[1]

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Abstract: This work makes the case that everything in the universe (all particles, fields and forces) is derived from the single building block of 4 dimensional spacetime. The tremendously large impedance of spacetime (c^3/G) permits small amplitude waves in spacetime to be the universal building block. The spacetime wave-based fermion model is shown to plausibly possess the correct spin, energy and the ability to appear to be point particles in experiments. This model also generates the weak gravity curvature of spacetime and the gravitational force between particles. The electrostatic force between fundamental particles is also derived and shown to be related to the gravitational force through a simple difference in exponents. A new constant of nature is proposed which converts electrical charge into a strain of space. The distortion of spacetime produced by photons is also analyzed.

Keywords: spacetime field, impedance of spacetime, zero point energy, gravitation, unification of forces, theory of everything, aether

1. Introduction

Quantum systems present many characteristics which can be described mathematically but cannot be understood conceptually. For example, a carbon monoxide molecule isolated in a vacuum can only rotate at integer multiples of 115 GHz. What enforces this quantized angular momentum? Why do fundamental particles exhibit wave-particle duality and probabilistic characteristics? What is the mechanism by which particles produce curved spacetime?

Generations of physicists have been unable to bring conceptual understanding to the foundational questions of both quantum mechanics (QM) and general relativity (GR). In physics, we start with assumptions and extract hidden implications using advanced mathematical analysis. However, if a problem is missing an essential assumption, no amount of mathematical analysis of the other required assumptions can successfully solve the problem. It is proposed that our current view of the universe is missing an essential starting assumption. The currently accepted starting assumptions are sufficient to achieve mathematical equations which agree with experiments, but they are not sufficient to give conceptually understandable explanations of many QM and GR effects including the mechanism by which matter curves spacetime. This paper will attempt to show that the missing fundamental assumption is: The universe is only spacetime.

This assumption is intended to convey the idea that all particles, all fields and all forces are just different aspects of 4 dimensional spacetime. If this assumption can be proven correct, it has a great deal of appeal. It would unify not only the forces of nature, but also the 17 particles of the standard model would all be related because they would be different excitations of the single spacetime field. Even the modeling of molecules in physical chemistry would achieve a new level of conceptual understanding. What is being proposed is that the fabled "theory of everything" might actually be possible if it can be shown that physics has an underlying simplicity expressed in the proposed missing assumption: The universe is only spacetime.

To understand how this assumption is plausible, it is first necessary to describe the model of spacetime that allows spacetime to be the single building block of everything in the universe. The usual descriptions of spacetime come from GR. However, it is proposed that GR describes only the macroscopic properties of 4 dimensional spacetime. For spacetime to be the single constituent of everything, it is necessary to expand the model of spacetime to include the small scale properties

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[1] Macken, JA (2015), Spacetime Based Foundation of Quantum Mechanics and General Relativity, in: Nascimento, MA et al. (eds.), Progress in Theoretical Chemistry and Physics **29**, Springer Switzerland pp. 219-245
DOI 10.1007/978-3-319-14397-2_13

of the vacuum obtained from QM. As John Archibald Wheeler said [1] "Empty space is not empty… The density of field fluctuation energy in the vacuum argues that elementary particles represent percentage-wise almost completely negligible change in the locally violent conditions that characterize the vacuum." It is this energetic form of the vacuum that must be combined with the macroscopic properties of spacetime to obtain the proposed single building block of all particles, fields and forces in the universe.

2. Zero Point Energy and the Spacetime Field

Taking John Wheeler's advice, we will start by modeling the energetic vacuum rather than initially attempting to model particles or forces. The quantum mechanical properties of the vacuum goes by many names including zero point energy (ZPE), vacuum energy, vacuum fluctuations, quantum foam, etc. Even the uncertainty principle and the virtual particle pair formation/annihilation will be attributed to these vacuum fluctuations. Field theory states that the vacuum can be viewed as if it is filled with harmonic oscillators [2] with energy $E = \frac{1}{2}\hbar\omega = \frac{1}{2}\hbar c/\lambda\!\!\!^{-}$ where lambda bar is $\lambda\!\!\!^{-} = c/\omega = \lambda/2\pi$. The volume V of each harmonic oscillator is a function of the wavelength which will be expressed as volume $V = k\lambda\!\!\!^{-3}$ where k is a numerical factor near 1. This implies that the quantum vacuum has a tremendous energy density [2]. For example, the implied energy density U is $U = k\hbar\omega^4/c^3$ where the angular frequency ranges from zero to a maximum of ω. In quantum field theory it is commonly assumed that the maximum frequency is equal to Planck angular frequency $\omega_p = \sqrt{c^5/\hbar G} \approx 1.9\times10^{43}$ s^{-1}. The implied energy density of the quantum vacuum is therefore approximately equal to Planck energy density $U_p = c^7/\hbar G^2 \approx 4.6\times10^{113}$ J/m^3. For comparison, the "critical" energy density of the universe obtained from GR is about 10^{-9} J/m^3. This is the famous 10^{120} discrepancy between the GR and QM. It is usually assumed that the energy density of the universe obtained from GR and cosmological observation must be correct and that some unknown large effect must cancel out what appears to be a ridiculously large energy density from QM. However, there are two problems with this. First, the cancelation must be carefully calibrated to cancel 10^{113} J/m^3 but leaving the 10^{-9} J/m^3 energy density that we observe. Second, a cancelation must also leave all the physical and theoretical effects required by QM, quantum electrodynamics and quantum chromodynamics.

If we are assuming that the universe is only spacetime, then we are not anxious to get rid of the tremendous energy density of the vacuum. In fact, the vacuum energy is essential to the spacetime model that allows spacetime to build everything in the universe. Rather than declaring that this large vacuum energy must be eliminated, we will accept and quantify the fluctuations of spacetime that result in this vacuum energy density. Once this is done, we can see if the models of the vacuum energy and the observable energy in the universe are somehow different in a way that allows both to peacefully coexist.

The obvious way that the vacuum might possess energy is if there are oscillating distortions (waves) in the vacuum. However, the wave amplitude would have to be small because large amplitude waves would be detectable and violate conservation laws. The uncertainty principle does allow waves to exist in spacetime provided that the amplitude of these waves are so small that the waves are not detectable as discrete waves. If these random waves existed, they would introduce noise into our distance and time measurements. The question of the theoretical limit (device independent) to the accuracy of a distance measurement between two points has been examined and found [3-7] to be on the order of Planck length $L_p = \sqrt{\hbar G/c^3} \approx 1.6\times10^{-35}$ m. In other words, waves which modulate the distance between two points by ± Planck length would be undetectable and therefore allowed. Similarly, an analysis of the fundamental minimum detectable unit of time (difference between clocks) has been made [4, 5] and found to be on the order of Planck time $T_p = \sqrt{\hbar G/c^5} \approx 5.4\times10^{-44}$ s. Therefore, waves in spacetime can slightly modulate the rate of time. Clocks in flat spacetime can speed up and slow down in a way that produces a maximum difference between clocks of $\pm T_p$. Waves in spacetime which have displacement amplitudes of $\pm L_p$ and $\pm T_p$ will be called "Planck amplitude waves". Unlike virtual particle pairs, Planck amplitude waves in spacetime can exist indefinitely because these waves are undetectable even with a long observation time. This is a fundamental property of spacetime that is not only allowed by the uncertainty principle, but in this model this turbulence causes the uncertainty principle.

It should be mentioned that the Planck amplitude waves in spacetime are a completely different concept than the granularity or pixelation proposed by loop quantum gravity. This granularity (pixelation) of loop quantum gravity is not sinusoidal wave oscillations. The pixelation model of spacetime is stagnant. It does not possess the tremendous energy density required to explain the 10^{113} J/m^3 of ZPE. In the remainder of this paper, the term "spacetime field" will be used to indicate the model of spacetime proposed here which is filled with Planck amplitude waves ($\pm L_p$ and $\pm T_p$) at all frequencies up to Planck angular frequency $\omega_p = \sqrt{c^5/\hbar G} \approx 1.9\times10^{43}$ s^{-1}.

There is another insight that can be extracted from our starting assumption. Since an objective is to construct fundamental particles out of waves in spacetime, those waves must be able to affect proper volume and the rate of time. This is said because a particle (mass) affects the rate of time and proper volume in the surrounding spacetime (matter curves spacetime). If this model is going to explain this effect, it is most reasonable to first explore the possibility that particles are made of waves in spacetime that modulate both the rate of time and proper volume. Gravitational waves are waves in the medium of spacetime, but they do not modulate the rate of time or proper volume. For example, a gravitational wave would convert a spherical volume into an oscillating ellipsoid which has the same volume and rate of time as the spherical volume. The only type of wave that would affect time and volume is a dipole wave in spacetime. This is a theoretical concept that would be the simplest type of wave in spacetime. However, it barely gets mentioned in standard texts on GR because dipole waves in spacetime are impossible on the macroscopic scale covered by GR. For example, in the 1300 page tome titled Gravitation [1], dipole waves in spacetime receive only a three line mention which can be paraphrased as *there can be no mass dipole radiation because the second time derivative of mass dipole is zero* $\ddot{d} = \dot{p} = 0$. If dipole waves existed in spacetime on the macroscopic scale, they would violate the conservation of momentum and the conservation of energy. However, QM permits dipole waves to exist in spacetime provided that the displacement amplitude is limited to $\pm L_p$ and $\pm T_p$. This is no problem because we have already accepted this limitation for any energetic waves to exist in spacetime. Therefore, the spacetime field model being developed will assume dipole waves in spacetime with the Planck amplitude limitation.

To test the contention that ZPE is Planck amplitude dipole waves in spacetime, we will start with an equation that gives the intensity I of a wave with amplitude A at angular frequency ω propagating in a medium with impedance Z.

$$I = kA^2\omega^2 Z \qquad (1)$$

This is a universal equation applicable to waves of any kind provided that the terms in this equation have compatible units. For example, electromagnetic (EM) radiation usually has intensity expressed as electric field strength and the impedance is expressed as the impedance of free space Z_o which has units of Ohms $Z_o \approx 377\Omega$. These units are not compatible with the units of intensity (watts/m^2 = kg/s^3) and frequency (s^{-1}) in Eq. (1). However, Eq. (1) can be used to express the intensity of sound waves, gravitational waves and the proposed Planck amplitude dipole waves in spacetime. For waves in spacetime, we would need to designate the impedance associated with the properties of spacetime. Fortunately reference [8] has identified the impedance of spacetime Z_s from gravitational wave equations.

$$Z_s \equiv c^3/G \approx 4.04\times10^{35} \text{ kg/s} \qquad (2)$$

In order to use $Z_s = c^3/G$ in Eq. (1) it is necessary to express the amplitude A in compatible units. When impedance is expressed in units of kg/s, the amplitude must be expressed as dimensionless strain amplitude. For example, if the spatial displacement of spacetime is $\pm L_p$, then the strain amplitude (maximum slope) of a wave with wavelength λ would be $A = L_p/\lambdabar$ where $\lambdabar \equiv \lambda/2\pi = c/\omega$. Similarly, if the temporal displacement of flat spacetime is $\pm T_p$, then the strain amplitude is $A = T_p\omega$. These are equivalent, therefore Planck length and Planck time displacements of spacetime translate into strain amplitudes of: $A = L_p/\lambdabar = T_p\omega$.

It is possible to expand Eq. (1) into several useful equations if we presume that the fluctuations of spacetime represent strongly interacting energy propagating at the speed of light (explained later). Such a wave would exert radiation pressure if it interacted with an object in a way that caused the wave to be transformed in some way. For example, absorption or emission of a wave propagating at c with power P exerts a force $F = P/c$. Combining this with Eq. (1) we obtain Eq. (3) which is the force exerted by a wave with amplitude A and angular frequency ω propagating at the speed of light in a medium with impedance Z exerted over area a. Eq. (4) is the energy density U of energy propagating at c and Eq. (5) is the energy E in a wave propagating at the speed of light filling volume V.

$$F = kA^2\omega^2 \mathcal{Z} \mathsf{a}/c \qquad (3)$$

$$U = kA^2\omega^2 \mathcal{Z}/c \qquad (4)$$

$$E = kA^2\omega^2 \mathcal{Z} V/c \qquad (5)$$

We will test the concept that ZPE is caused by Planck amplitude fluctuations of spacetime. We will use Eq. (5) and assume a wave with strain amplitude $A = L_p/\lambdabar$ at angular frequency $\omega = \lambdabar/c$ in volume $V = k\lambdabar^3$.

$$E = \frac{kA^2\omega^2 \mathcal{Z} V}{c} = k\left(\frac{L_p}{\lambdabar}\right)^2 \omega^2 \left(\frac{c^3}{G}\right)\left(\frac{\lambdabar^3}{c}\right) = k\hbar\omega \qquad (6)$$

This calculation yields $E = k\hbar\omega$ which is the general form of the energy in the harmonic oscillators of ZPE ($E = \frac{1}{2}\hbar\omega$). We cannot establish that $k = 1/2$ for this equation, but this is merely a plausibility calculation intended to show a connection between ZPE and the spacetime field filled with Planck amplitude waves in spacetime. Also if these same substitutions are made into the energy density Eq. (4) we obtain $U = k\hbar\omega^4/c^3$. Reference [2] shows that this is the equation for the energy density of ZPE for all frequencies between zero and a cutoff frequency of ω. If we presume that this cutoff frequency is equal to Planck angular frequency $\omega_p = \sqrt{c^5/\hbar G}$ then the total energy density of ZPE would be a numerical factor k times Planck energy density $U_p = c^7/\hbar G^2 \approx 10^{113}$ J/m^3. This corresponds to the energy density of ZPE [2]. Also this tremendous energy density implies that the spacetime field generates a tremendous pressure. This will be discussed later.

Therefore, this is a successful test of the contention that ZPE can be explained using the starting assumption that the universe is only spacetime. This is also the first step in converting the starting assumption (the universe is only spacetime) into equations. Even though the fluctuations only displace spacetime by Planck length and Planck time, this small displacement is in a medium which has a tremendously large impedance $Z_s \equiv c^3/G \approx 4.04 \times 10^{35}$ kg/s. The fact that the spacetime field has impedance means that it has elasticity. In order for a sound wave to propagate through an acoustic medium, the acoustic medium must be capable of absorbing energy and returning energy to the sound wave. Similarly, a wave propagating in a sea of Planck amplitude waves in the spacetime field would slightly compress and expanding these waves thereby slightly changing the energy of the waves that create ZPE. This gives spacetime the ability to absorb and return energy to waves. The spacetime field does not merely have waves, the spacetime field fundamentally is a sea of Planck amplitude waves. This model of the proposed energetic spacetime field explains why spacetime is such a stiff medium for gravitational wave propagation and how spacetime achieves the tremendously large impedance of c^3/G.

We know that virtual particle pairs are continuously being formed in the energetic vacuum and annihilated back into the vacuum. It is not too great a stretch to assume that these virtual particle pairs are actually another form of spacetime. Real particles possess quantized angular momentum (spin) while virtual particle pairs have no total angular momentum. We will test the hypothesis that real particles are also a form of spacetime which incorporates angular momentum. Next a spacetime based model of a fundamental particle will be presented. The initial presentation will not include the underlying reasoning. However, once the characteristics are established, the proposed spacetime particle model will be subjected to 8 plausibility tests which include a test of energy, angular momentum and the ability to appear to be a point particle. Therefore, the viability of the particle model will be determined in the testing phase.

3. Spacetime Model of a Fundamental Particle

To help explain the proposed model of a spacetime particle, we will first make an analogy to a superfluid which contains a small amount of angular momentum. For example, a Bose-Einstein condensate is a superfluid. When angular momentum is introduced into this condensate, the bulk of the superfluid does not rotate. Instead, the angular momentum is broken into small rapidly rotating vortices which each contain $\hbar$ of quantized angular momentum. These are surrounded by the vast majority of the superfluid which is not rotating. References [9-11] show pictures of these rapidly rotating vortices and give a more detailed explanation.

The analogy to a vortex in a superfluid is that a fundamental fermion such as an electron is proposed to be a rapidly rotating Planck amplitude wave in spacetime with $\hbar/2$ of quantized angular momentum. It is confined and isolated by the surrounding sea of superfluid-like Planck amplitude waves which lack angular momentum. More specifically, a fundamental fermion with internal energy E_i is proposed to be a Planck amplitude wave propagating at the speed of light but circulating within a spherical volume one Compton wavelength λ_c in circumference. The rotating wave does not have a sharp boundary, but for mathematical analysis, it can be considered to have a radius equal to the reduced Compton wavelength $\bar{\lambda}_c$. Its rotational rate is equal to the Compton angular frequency ω_c and its strain amplitude will be designated as A_s. Eq. (7-9) quantify these terms.

$$\omega_c = E_i/\hbar = c/\bar{\lambda}_c \tag{7}$$

$$\bar{\lambda}_c = \hbar c/E_i = c/\omega_c = \hbar/mc \tag{8}$$

$$A_s = L_p/\bar{\lambda}_c = T_p\omega_c \tag{9}$$

The sea of Planck amplitude waves in spacetime are proposed to be the most perfect superfluid possible. Angular momentum that originated at the Big Bang is isolated into ½$\hbar$ and $\hbar$ quantized units. While angular momentum cannot be destroyed, only specific combinations of wave amplitude and rotational frequency achieve stability through the interaction with the surrounding spacetime field. These few amplitudes and frequencies that are stable or semi-stable are the fermions and bosons of the standard model. They can propagate through the superfluid spacetime field without energy loss. The previously mentioned 10^{120} discrepancy in the energy density of the universe between GR and QM is proposed to be the difference between the average energy density of fermions and bosons which possess quantized angular momentum and the energy density of the Planck amplitude waves which lack angular momentum and form the spacetime field.

There is no conflict between these two energy densities. The homogeneous waves in spacetime which lack angular momentum are responsible for giving flat spacetime its properties (its physical constants) such as Z_s, c, G, $\hbar$, ε_o, etc. The fermions with quantized angular momentum represent distortions in the otherwise homogeneous spacetime field. If we average these distortions over all space, they represent only about 1 part in 10^{120} of the average energy density possessed by the spacetime field. However, a high density of fermions, for example in a neutron star, can produce a substantial localized excess energy density. The conditions that create a black hole can be related to producing 100% modulation of the properties of the spacetime field at a particular wavelength, amplitude and frequency. This point will be analyzed later.

The energy density of the homogeneous spacetime field does not create its own gravity. Instead, gravity is the distortion of this homogeneous field caused by inhomogeneities in the form of rotating Planck amplitude waves possessing quantized angular momentum. These distortions of the spacetime field extend far beyond the particle's spherical volumes previously described. This external effect will be discussed later.

In this model, a counter rotating virtual particle pair is two Planck amplitude waves of the spacetime field which momentarily achieve the amplitude and frequency of a fundamental particle pair. However, there is no quantized angular momentum. Therefore, the deception lasts for only for a time equal to $1/\omega_c$ at which point the virtual particle pair appears to be annihilated. ($1/\omega_c \approx \Delta t$ in the uncertainty principle) The universal spacetime field can appear to be the multiple fields of the standard model because there are multiple resonances which produce different types of virtual particle pairs. Currently, field theory considers that each of the 17 fundamental particles of the standard model has its own field [12]. This implies that the universe has at least 17 overlapping fields. This unappealing concept is replaced by the more appealing concept of a single spacetime field with multiple resonances which achieve all the particles, fields and forces.

4. Testing of the Particle Model

4.1 Energy and Angular Momentum Test

The first of the plausibility tests will examine whether this model plausibly achieves the required energy for a fundamental particle. We will not be attempting to predict the energy of specific fundamental particles. Instead we will take Eq. (5) and substitute $A = A_s$, $\omega = \omega_c$, $Z = Z_s$, and $V = k\bar{\lambda}_c^3$. The answer obtained with these substitutions is: $E = kE_i$. In words, the proposed amplitude A_s, frequency ω_c, radius $\bar{\lambda}_c$ and impedance Z_s generates the correct internal energy E_i of a fundamental particle if $k = 1$. For example, an electron has strain amplitude of $A_s \approx 4.18 \times 10^{-23}$, a Compton angular frequency of $\omega_c \approx 7.76 \times 10^{20}$ s^{-1}, and a reduced Compton wavelength of $\bar{\lambda}_c \approx 3.86 \times 10^{-13}$ m. This is an extremely weak rotating distortion of spacetime. However, because of the large value of Z_s, substituting the electron's values into Eq. (5) achieves the electron's energy of $E_i \approx 8.19 \times 10^{-14}$ J. For comparison, if a point particle model is used, then there is no internal structure that connects to the electron's Compton frequency, Compton wavelength or internal energy. The implied infinite energy density speaks to the inadequacy of the point particle concept.

Next, we will check if the spacetime particle model can plausibly possess angular momentum of $\mathcal{L} = \hbar/2$. If the particle model had all the wave energy circulating at the speed of light around the circumference like a rotating hoop, then the particle model would have angular momentum of $\mathcal{L} = \hbar$. This follows from $\mathcal{L} = pr$ where the rotating hoop model would have $p = E_i/c$ and $r = ƛ_c = \hbar c/E_i$. However, the spacetime model has the energy more uniformly distributed throughout the internal volume. This lowers the momentum term to $p < E_i/c$. This is equivalent to having a moment of inertia more like a rotating disk than a rotating hoop. The rotation is also somewhat chaotic which also reduces the angular momentum. The exact energy distribution has not been determined, but there is a wide range of possibilities that can achieve $\mathcal{L} = \hbar/2$. In fact, achieving this angular momentum would become a design criteria in choosing the "correct" energy distribution. For comparison, a point particle or even a Planck length vibrating string is physically incompatible with achieving the angular momentum requirement.

At the start of this paper the question was asked: What mechanism enforces quantized angular momentum on a rotating CO molecule? It is common for physics professors to explain to their students that a fundamental particle such as an electron possess "intrinsic angular momentum" or "spin" which is QM phenomena with no interpretation from classical mechanics. While it is impossible to see any physical rotation of an electron, molecules possess a quantized physical rotation (quantized angular momentum) which can be physically proven. In this model, the quantized angular momentum of a molecule is "enforced" by the fact that the molecule is itself made of rotating quantum of spacetime energy existing in the sea of the superfluid spacetime field. Is it not reasonable that fundamental particles also have a physical rotation? Saying that an electron has "spin" without physical angular momentum is an admission that the currently accepted models of fermions are inadequate.

For comparison, the spacetime particle model does not just have angular momentum as an added feature. Instead angular momentum is the central feature that imparts quantization. Quantized angular momentum is the feature that distinguishes fermions and bosons from ZPE which has about 10^{120} times more energy in the universe. This proposed model offers a conceptually understandable explanation of "spin".

4.2 *Curved Spacetime Test*

The next test is to see if the spacetime particle model plausibly produces the correct curvature of spacetime in the surrounding spacetime. According to GR, matter causes the surrounding spacetime to have a decrease in the rate of time and an increase in proper volume relative to Euclidian geometry.

$$\frac{dt}{d\tau} = \frac{dr}{dR} = \left(1 - \left(\frac{2Gm}{c^2 R}\right)\right)^{-1/2} \approx 1 + \frac{Gm}{c^2 r} \qquad (10)$$

t = coordinate time measured on a stationary clock infinitely far from the mass - effectively zero gravity

τ = proper time measured on a local clock in gravity moving along the same world line as a test particle

r = proper radial distance

R = circumferential radius - radial coordinate - circumference around a mass divided by 2π.

Eq. (10) is standard for general relativity and will not be explained further. This is the temporal and spatial curvature of spacetime caused by mass m. The weak gravity approximation is $dt/d\tau \approx 1 + Gm/c^2 r$. In flat spacetime $dt/d\tau = 1$, therefore the term that expresses the curvature of spacetime is $Gm/c^2 r$. For a single fundamental particle at a distance equal to or greater than $ƛ_c$, this weak gravity approximation is accurate to better than about 1 part in 10^{40}.

The next plausibility test will be to see if the spacetime particle model can generate this spacetime curvature. If a fundamental particle is imagined as a point particle, and if spacetime is visualized as an empty void, then there is no obvious way that the particle can cause spacetime curvature. However, if the energetic spacetime field surrounds a rotating spacetime dipole wave which modulates the rate of time and proper volume, this is a promising combination to achieve spacetime curvature.

The spacetime field has finite characteristics such as a maximum frequency, a maximum strain and a maximum energy density. Therefore it follows from these boundary conditions that ***spacetime should be a nonlinear medium for wave propagation***. The fundamental particle model (rotating dipole wave) produces a long range disturbance (standing waves) in the surrounding spacetime field. If the spacetime field is a nonlinear medium, then waves in spacetime should have both a linear component and a nonlinear component. The spacetime particle model has a strain amplitude of A_s at distance $r = \lambdabar_c$. The dynamic strain produced by the rotating dipole wave in the nonlinear spacetime field typically would be: $Strain = A_s \sin\omega t + \left(A_s \sin\omega t\right)^2$.... There would also be higher order terms where A_s is raised to higher powers. However, since A_s is typically in the range of 10^{-20} for known fundamental particles, we will calculate an approximation which ignores powers higher than the square term. Therefore the dominant linear component is $A_s \sin\omega t$ and the much weaker nonlinear component is $\left(A_s \sin\omega t\right)^2$. The physical interpretation of this is that the distortion of the spacetime field produced by the presence of a spacetime particle (fermion) has a linear component associated with the particle's electric field and a nonlinear component associated with the particle's gravitational field. We will first examine the nonlinear (gravitational) component.

$$\left(A_s \sin\omega t\right)^2 = \tfrac{1}{2}A_s^2 - \tfrac{1}{2}A_s^2 \sin 2\omega t \qquad (11)$$

Eq. (11) expands, this nonlinear component to reveal a non-oscillating term A_s^2 and a term that is oscillating at twice the Compton angular frequency $A_s^2 \sin 2\omega t$. This oscillating component of gravity is essential for the generation of curved spacetime and is a prediction of this spacetime model of gravity. However, this oscillating component is not measurable and will not be discussed further.

At this point we are going to pause for a moment and explain that the following analysis is initially going to be somewhat simplified. It will result in the correct magnitude of forces, but the implied vector direction of the gravitational force will initially be wrong. However, this analysis is valuable because it introduces important correct concepts in a simplified way. Later a revised analysis will be offered which is based on pressure differences. This will give the same magnitude of forces but with the correct vector.

We know the linear amplitude (A_s) and nonlinear amplitude (A_s^2) at distance $r = \lambdabar_c$ measured from the center of the particle. However, how does this nonlinear amplitude change with distance? Since we are dealing with amplitude, we will assume the amplitude decreases inversely with distance and it must match the known amplitude (A_s^2) at distance $r = \lambdabar_c$. To achieve this match, the non-oscillating distortion of spacetime must scale inversely with the number N of reduced Compton wavelengths $\lambdabar_c$ units measured from the center of the particle model. This is said because $N = 1$ at $r = \lambdabar_c$ if we define $N \equiv r/\lambdabar_c$.

Combining these factors, the non-oscillating gravitational amplitude should decrease with $1/N$. We can then define a new amplitude associated with the non-oscillating distortion of spacetime: $A_G \equiv A_s^2/N$. Next we find the magnitude of A_G.

$$A_G = \frac{A_s^2}{N} = \left(\frac{L_p^2}{\lambdabar_c^2}\right)\left(\frac{\lambdabar_c}{r}\right) = \frac{Gm}{c^2 r} \qquad (12)$$

This is an important success for the spacetime model of particles. When we evaluate the non-oscillating distortion of spacetime produced by spacetime being a nonlinear medium, we obtain the weak gravity curvature of spacetime induced by a single fundamental particle. Since the gravitational effect is extremely weak for any of the known fundamental particles even at distance $\lambdabar_c$, this is virtually exact to an accuracy better than 1 part in 10^{40}. Finally, it is usually assumed that matter causes curved spacetime. However, the proposed model implies that waves in spacetime cause both matter and a non-oscillating strain in spacetime we know as curved spacetime.

4.3 Gravitational and Electrostatic Force Test

Next we will calculate the magnitude of the gravitational force between two of the same spacetime particles, each with energy E_i. For this calculation, we will use Eq. (3) and make the following substitutions:

$A = A_G = Gm/c^2 r$, $\omega = \omega_c = c/\lambdabar_c$, $Z = Z_s = c^3/G$, $a = k\lambdabar_c^2$, $\lambdabar_c = \hbar c/E_i = \hbar/mc$

$$F_G = \frac{kA_G^2\omega_c^2 Z_s a}{c} = k\left(\frac{Gm}{c^2 r}\right)^2 \frac{c^2}{\lambdabar_c^2}\frac{c^3}{G}\frac{\lambdabar_c^2}{c} = k\frac{Gm^2}{r^2} \qquad (13)$$

Therefore we have successfully obtained the magnitude of the gravitational force between two of the same particles $m_1 = m_2$ if we assume $k = 1$.

Next we will calculate the magnitude of the force for the linear term (the first order effect). We know that at distance $r = \lambdabar_c$ the strain amplitude is $A_s = L_p/\lambdabar_c$. Again we assume that it decreases inversely with distance which implies $1/N$ scaling. Combining these we obtain an amplitude that will be designated

$A_E = k\,A_s/N = k\,L_p/\bar{\lambda}_c N$. Another substitution that will be used is Planck charge: $q_p = \sqrt{4\pi\varepsilon_o \hbar c}$.

$$F_E = \frac{kA_E^2\omega_c^2\mathcal{Z}_s\mathsf{a}}{c} = k\left(\frac{L_p}{\bar{\lambda}_c N}\right)^2 \frac{c^2}{\bar{\lambda}_c^2}\frac{c^3}{G}\frac{\bar{\lambda}_c^2}{c} = k\frac{\hbar c}{r^2} = k\frac{q_p^2}{4\pi\varepsilon_o r^2} \quad (14)$$

Therefore when we assume $A = A_E = k\,L_p/\bar{\lambda}_c N$ and $k = 1$, then we obtain the Coulomb force equation that corresponds to the magnitude of the electrostatic force between two electrically charged particles which each have Planck charge $\left(q = q_p = \sqrt{4\pi\varepsilon_o\hbar c}\right)$. Planck charge is about 11.7 times larger ($\alpha^{-1/2}$ times larger) than elementary charge *e*. It is not surprising that this calculation would result in the force generated by Planck charge and not the force generated by elementary charge *e*. We are actually calculating the theoretical maximum electrostatic force which assumes a coupling constant equal to 1. For electrostatic force, Planck charge corresponds to a coupling constant of 1 whereas elementary charge *e* is known to have a coupling constant equal to α, the fine structure constant. The source of α is unknown. We will accept Planck charge as the more fundamental value of charge for a comparison of gravitational and electrostatic forces. The symbol F_E will indicate the force between two Planck charge spacetime particles. Later some equations will be converted to elementary charge *e*. The symbol F_e will be used to indicate the force between two elementary charge *e* spacetime particles.

Previously we assumed the simplified case of two of the same energy particles. We will next assume two spacetime particles with different energies (energy E_1 and E_2). Then there would be two different reduced Compton wavelengths $\bar{\lambda}_{c1}$ and $\bar{\lambda}_{c2}$ which results in a single separation distance *r* having two different values of *N* which will be designated as $N_1 = r/\bar{\lambda}_{c1}$ and $N_2 = r/\bar{\lambda}_{c2}$. Also there would be two different strain amplitudes $A_{s1} = L_p/\bar{\lambda}_{c1}$ and $A_{s2} = L_p/\bar{\lambda}_{c2}$ as well as a composite area $a = k\bar{\lambda}_{c1}\bar{\lambda}_{c2}$.

$$F_G = k\left(\frac{A_{s1}^2A_{s2}^2}{N_1N_2}\right)\left(\frac{c^2}{\bar{\lambda}_{c1}\bar{\lambda}_{c2}}\right)\left(\frac{c^3}{G}\right)\left(\frac{\bar{\lambda}_{c1}\bar{\lambda}_{c2}}{c}\right) = k\frac{Gm_1m_2}{r^2} \quad (15)$$

$$F_E = k\left(\frac{A_{s1}A_{s2}}{N_1N_2}\right)\left(\frac{c^2}{\bar{\lambda}_{c1}\bar{\lambda}_{c2}}\right)\left(\frac{c^3}{G}\right)\left(\frac{\bar{\lambda}_{c1}\bar{\lambda}_{c2}}{c}\right) = k\frac{q_p^2}{4\pi\varepsilon_o r^2} \quad (16)$$

Note that the only difference between the intermediate portion of (15) and (16) is that the gravitational force Eq. (15) has the strain amplitude terms squared ($A_{s1}^2A_{s2}^2$) and the electrostatic force Eq. (16) has the strain amplitude terms not squared $\left(A_{s1}A_{s2}\right)$. The tremendous difference between the gravitational force and the electrostatic force is predominantly due to a difference in exponents. For example, an electron has strain amplitude of $A_s \approx 4.18\times10^{-23}$. Therefore the vast difference between the gravitational force and the electrostatic force comes from the difference in exponents: $\left(A_s^2\right)^2 \approx 10^{-90}$ versus $A_s^2 \approx 10^{-45}$. Other factors such as α are relatively unimportant.

4.4 Unification of Forces

The spacetime model of the universe predicted that gravity was a nonlinear effect that scaled with wave amplitude squared (higher powers ignored) while the electrostatic force scales with wave amplitude to the first power. This is a tangible step towards the unification of forces. While Eq. (13-16) show this square exponent relationship, a search was initiated for equations that would better demonstrate the predicted difference in exponents between these two forces. This difference in exponents is most apparent when the force equations are expressed in dimensionless Planck units and the separation distance is given using *N*, the number of reduced Compton wavelengths $\bar{\lambda}_c$ which corresponds to the number of particle radius units. When force magnitude is expressed in dimensionless Planck units, this will be designated with an underline such as: $\underline{F} = F/F_p$. This represents a ratio between the specified force *F* and Planck force $F_p = c^4/G$ which is the largest force that spacetime can exert [13]. For example Planck force is the force between two of the same size black holes as they are about to merge (ignoring a numerical factor near 1). Similarly, energy in dimensionless Planck units will be $\underline{E} = E/E_p$ where Planck energy is $E_p = \sqrt{\hbar c^5/G}$. When a particle's energy is expressed in dimensionless Planck units, it is a ratio between the particle's energy and the largest energy that a quantized particle can possess. In addition to previously mentioned substitutions, the following

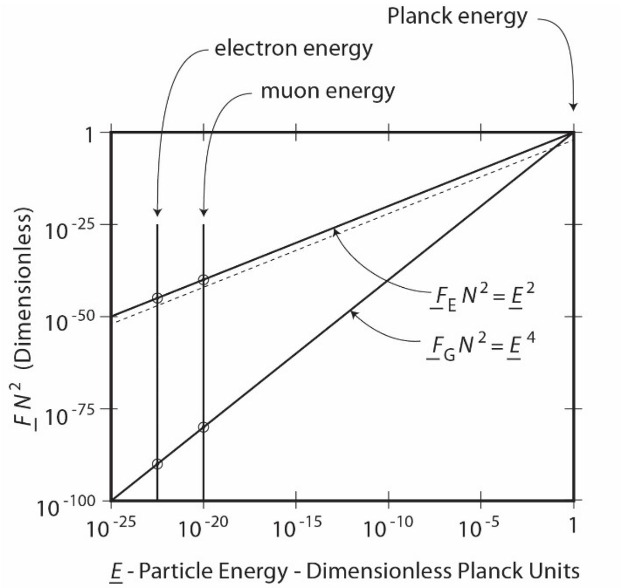

Fig. 1. Comparison of forces between two hypothetical fundamental particles, each with Planck charge and the same mass/energy. Underlined symbols: $\underline{F}_E$, $\underline{F}_G$, and $\underline{E}$ are in dimensionless Planck units. The plotted equations relate dimensionless electrostatic force $\underline{F}_E$ and gravitational force $\underline{F}_G$ to particle energy $\underline{E}$ and the number N of reduced Compton wavelengths separating particles.

substitutions will be used: $m_1 = m_2$, $k = 1$ and $A_s = L_p / \bar{\lambda}_c = E / E_p = \underline{E}$.

$$\underline{F}_G = \frac{F_G}{F_p} = \frac{kA_G^2\omega_c^2\mathcal{Z}_s\mathrm{a}}{cF_p} = \left(\frac{A_s^2}{N}\right)^2 \frac{c^2}{\bar{\lambda}_c^2}\frac{c^3}{G}\frac{\bar{\lambda}_c^2}{c}\frac{G}{c^4} = \frac{\underline{E}^4}{N^2} \quad (17)$$

$$\underline{F}_E = \frac{F_E}{F_p} = \frac{kA_E^2\omega_c^2\mathcal{Z}_s\mathrm{a}}{cF_p} = \left(\frac{A_s}{N}\right)^2 \frac{c^2}{\bar{\lambda}_c^2}\frac{c^3}{G}\frac{\bar{\lambda}_c^2}{c}\frac{G}{c^4} = \frac{\underline{E}^2}{N^2} \quad (18)$$

Eq. (17) and (18) can be written as $\underline{F}_G N^2 = \underline{E}^4$ and $\underline{F}_E N^2 = \underline{E}^2$ which are plotted in figure 1. This is a log-log graph that uses dimensionless Planck units of force and energy. To give a sense of the energy scale in dimensionless Planck units, three familiar energies are designated. These are: Planck energy $\underline{E} = 1$, an electron's energy $\underline{E} = 4.18 \times 10^{-23}$ and a muon's energy $\underline{E} = 8.65 \times 10^{-21}$. Planck energy is the largest energy that a particle with quantized spin can have. If a photon or fermion had Planck energy, it would form a black hole.

The Y axis is values of the product $\underline{F}N^2$ which is force in dimensionless Planck units (either $\underline{F}_E$ or $\underline{F}_G$) times N^2. The equation $\underline{F}_E N^2 = \underline{E}^2$ assumes both particles have Planck charge therefore a coupling constant of 1. The close dashed line shows the force that would be exerted if both particles have charge e rather than charge q_p. This dashed line is a factor of α less than the Planck charge line but on this log-log graph a factor of 137 is small when the entire Y axis scale covers a factor of 10^{100}.

Figure 1 is best understood with some examples. Since both particles have the same radius ($\bar{\lambda}_c$), we will initially make the assumption that the two particles are separated by this distance ($r = \bar{\lambda}_c$ and $N = 1$ therefore $\underline{F}_G = \underline{E}^4$ and $\underline{F}_E = \underline{E}^2$). This is actually an unrealistic assumption because at this distance quantum mechanics becomes dominant and the uncertainty in position prevents a precise designation of position. Also the work done bringing two charged particles this close together would substantially increase the energy of the two particles and distort the forces. However, it is possible to assume $r = \bar{\lambda}_c$ if we think of this as merely an extrapolation from a longer distance to a distance equal to the radius of the spacetime particle model. At this important separation distance we obtain the following relationships:

$$\underline{F}_G = \underline{F}_E^2 \quad (19)$$

$$F_G / F_E = F_E / F_p \quad (20)$$

Eq. (19) is so important that it needs to be restated in words. Assuming two of the same energy particles with charge $q = q_p$ and separated by $r = \bar{\lambda}_c$, the gravitational force equals the square of the electrostatic force when both forces are in dimensionless Planck units. Also, Eq. (20) states that at this important separation distance, the ratio of the gravitational force to the electrostatic force equals the ratio of the electrostatic force to Planck force. This implies that at $r = \bar{\lambda}_c$ a symmetry exists between the gravitational force, the electrostatic force and Planck force.

If these forces are assumed to be transferred by the exchange of virtual photons, gravitons or the geometry of spacetime, then the distance $\bar{\lambda}_c$ should not be particularly important and there should be no exponent relationship between the gravitational and electrostatic forces. The spacetime particle is stabilized by an interaction with the surrounding spacetime field. This produces distortions in the spacetime field which extend into the surrounding spacetime and scale as a function of $\lambdabar_c$. Details of these external distortions have not been discussed before, but they give rise to curved spacetime, electric/magnetic fields and de Broglie waves all of which scale with $\lambdabar_c$. These are large subjects beyond the scope of this paper. However, these and all the concepts presented in this paper are explained in greater detail in the online book titled The Universe Is Only Spacetime [14].

The equation $\underline{F}_G = \underline{F}_E^2$ clearly shows the square relationship between forces at the specific separation distance of $r = \lambdabar_c$ for $m_1 = m_2$ and $q = q_p$. Eq. (21) below shows that when separation distance is expressed as *N* multiples of $\lambdabar_c$, the square force relationship exists at arbitrary distance. To bring out this square relationship, Eq. (21) is written in a way that does not cancel some terms. Eq. (22) is the same as (21) except it is rewritten to expresses the ratio between forces F_G / F_E and duplicate terms are canceled.

$$\left(\frac{F_G}{F_p} N^2\right) = \left(\frac{F_E}{F_p} N^2\right)^2 \tag{21}$$

$$\frac{F_G}{F_E} = \frac{F_E}{F_p} N^2 \tag{22}$$

So far the electrostatic force equations have assumed Planck charge as implied by the symbol F_E. Since $q_p^2 = e^2 / \alpha$, the conversion to the force exerted between two elementary charges *e* is: $F_E = F_e / \alpha$. For example, Eq. (22) becomes Eq. (23) below.

$$\frac{F_G}{F_e} = \frac{F_e}{F_p} \frac{N^2}{\alpha^2} \tag{23}$$

Eq. (23) applies not only to charged leptons such as electrons or muons, but it can also be used to express the ratio of forces between two of the same hadrons, each with charge $\pm e$. For hadrons, the reduced Compton wavelength of the entire hadron is used. For example, the force ratio between two protons at any distance is $F_G / F_e \approx 8.1 \times 10^{-37}$. The right side of the Eq. (23) is also independent of separation because of offsetting effects of F_e and N^2.

Until now the forces have only been between two fundamental particles. However these forces are additive. Every particle in body *A* interacts with every particle in body *B*. The total of all these individual forces add up to the total gravitational and electrostatic forces between bodies *A* and *B* (still assuming weak gravity). A goal for the future will be to see if incorporating additional nonlinear effects achieves the exact equations of GR.

It is often said that gravity was united with the other forces at the start of the Big Bang when all the particles had Planck energy. Figure 1 shows that indeed the electrostatic and gravitational force graphs intersect (the same magnitude of force) when particle energy equals Planck energy $\underline{E} = E_p / E_p = 1$. However, the point of this graph and analysis is that even today when $E \neq E_p$ there is still a unification between the gravitational and electrostatic forces. For example, the electrostatic force graph line in figure 1 is the square root of the gravitational force graph line. The vast difference in the magnitudes of these forces comes from a simple difference in exponents. This relationship was previously unnoticed until the missing assumption (the universe is only spacetime) was adopted. The existence of these simple relationships provides support for this assumption and the proposed spacetime particle model.

The previous explanation was simplified. It contained correct components, but the model implied the continuous emission of waves and a repulsive force. The more complete explanation takes two chapters in the online companion book [14] and therefore is beyond the scope of this paper. However, a brief explanation of the key conceptual points will be given here. The proposed particle model has energy density which can be calculated using Eq. 4. Energy density U and pressure $\mathbb{P}$ both have units of kg/m^{2}s. Since the spacetime particle model has energy propagating at the speed of light in a confined volume, the energy density is directly equated to pressure. For example, an electron has a pressure of about 10^{24} N/m^2 which produces a force of about 0.2 N over the area of $\lambdabar_c^2$ for an electron. An electron is stable because its amplitude, frequency etc. interact with the surrounding spacetime field and achieve an offsetting pressure which stabilizes the structure.

In a gravitational field there is a gradient in the rate of time and proper volume (curved spacetime). The curved spacetime gradient affects the pressure exerted on opposite sides of an electron or other spacetime particle. This unequal pressure on opposite sides of the particle produces a net force. This net force is the gravitational force with the correct direction and magnitude. Even though gravity appears to be a force of attraction, it actually results from an imbalance in pressure which is a repulsive force exerted by the spacetime field.

This explanation involving pressure can be restated in a way that emphasizes the rotating dipole wave that forms a spacetime particle. The rotation occurs in curved spacetime which results in a type of modulation which incorporates many of the elements of the "simplified" explanation previously given.

4.5 Point Particle Test

Perhaps the biggest objection to the spacetime particle model is the fact that the model implies that fundamental particles have volume and internal structure. High energy collision experiments [15] seem to imply that an electron cannot be larger than roughly 10^{-18} m. Highly relativistic electrons can also probe the internal structure of a proton which has a radius of about 10^{-15} m. How can a particle with a radius larger than 10^{-13} m probe the internal structure of a proton with a radius of 10^{-15} m? Is the relatively large size of an electron not conclusive proof that the spacetime model of fundamental particles must be wrong? To analyze this question it is necessary to analyze the experiments more carefully. However, first it is necessary to add one characteristic to the spacetime particle model.

An analogy is going to be made between the communication that takes place between two entangled photons and the communication that takes place within a single spacetime particle. The single spacetime particle possesses quantized angular momentum of $\hbar/2$. It is not possible to momentarily interact with less than the entire quantized angular momentum. The interaction is all or nothing. If the probability of an interaction results in "nothing", then the two rotating distortions of spacetime merely pass through each other and there is no collision. There would be some electrostatic deflection but there would be no classical collision that would be expected if both particles were elastic spheres with a radius of 3.86×10^{-13} m. If there is a strong interaction (collision) the quantization implies that the internal communication within the spacetime particle must be instantaneous – just like the communication between entangled particles. The "news" of the collision is transferred instantaneously throughout the volume of the quantized wave and gives it particle-like properties. This is purely an internal property that allows the distributed spacetime wave with quantized angular momentum to respond to a perturbation as a single unit. No external information can be communicated faster than the speed of light because of this property.

The spacetime particle model is merely a rotating distortion of spacetime existing in a sea of spacetime waves that lack angular momentum. This is not a physical object like a vibrating string or a hard sphere with definable dimensions. The spacetime particle model has zero physical radius if the expectation is an object other than spacetime. Instead, an electron is essentially a quantum of angular momentum which produces a rotating distortion of the spacetime field. The amplitude, frequency, distribution and size of this rotating distortion of spacetime can change depending on the experiment or boundary conditions. For example, when an electron is bound to a proton to form a hydrogen atom, the electron loses energy and experiences different boundary conditions that change its volume and distribution compared to an isolated electron.

Similarly, colliding electrons also change their characteristics. Suppose that we imagine two electrons with internal energy of $E_i \approx 0.5$ MeV colliding with kinetic energy of $E_k \approx 50$ GeV. If they do interact (collide) the kinetic energy E_k is momentarily added to the spacetime particle's internal energy producing a new total energy of $E_i + E_k$. This would momentarily increase the rotational frequency to $\omega_{ck} = \hbar\left(E_i + E_k\right)$ and decrease the radius to $ƛ_{ck} = \hbar c/\left(E_i + E_k\right)$ where $ƛ_{ck}$ is the designation used to indicate the momentary reduced Compton wavelength when the colliding spacetime particle has absorbed additional energy E_k. For a 50 GeV collision, this momentarily decreases the radius by a factor of about 100,000 to $ƛ_{ck} \approx 10^{-18}$ m. This increase in energy and decrease in radius maintains the angular momentum at $\hbar/2$. An uncertainty principle calculation for an ultra-relativistic collision with special relativity $\gamma \approx E_k/mc^2$ has a momentum uncertainty of $\Delta p \approx \gamma mc$ and the uncertainty in position of $\Delta x \approx \frac{1}{2}\hbar c/E_k \approx \frac{1}{2}ƛ_{ck}$. Considering that there can also be partial overlap of these spacetime particles, it can be seen that the momentary radius $ƛ_{ck}$ is comparable to the uncertainty of the experiment. The electron's radius can never be measured because $\Delta x \approx ƛ_{ck}$. It is a classic case of the experiment distorting the property being measured and invalidating the measurement.

The maximum size of an electron has also been estimated by Hans Dehmelt [16, 17] from a comparison of the theoretical and experimental value of the electron's anomalous magnetic dipole moment (electron's *g*-factor). The QED theoretical *g*-factor calculation assumes the electron has zero radius and this theoretical value agrees with the experimental value to about 10 significant figures. This virtually exact agreement between experiment and theory is interpreted as implying that the electron must have a physical radius smaller than 10^{-22} m.

However, this reasoning does not apply to the proposed spacetime model of an electron. This model merely organizes a small part of the chaotic Planck amplitude waves in spacetime into a rotating quantized unit. The spacetime model of an electron has spatial and temporal strain with amplitude of $A_s \approx 4.18\times10^{-23}$. To put this incredibly small strain of spacetime in perspective, the rate of time difference (distortion) within an electron is so small that two clocks which differed by this factor would take 50,000 times the age of the universe before they differed by one second. Similarly, the spatial distortion within an electron is so small that expanding space by this factor would enlarge the radius of Jupiter's orbit by about the radius of a hydrogen atom. These considerations imply that an electron would produce a virtually undetectable difference between the experimental and theoretical values of the g-factor.

One final point concerning particle size. The highly successful Dirac equation [18] also supports this model. The Dirac equation assumes that an electron is always propagating at the speed of light. The average speed is less than *c* because the motion is mathematically characterized as $\pm c$. Erwin Schrodinger interpreted the Dirac equation. [19, 20] as implying that a point charge is undergoing "*zitterbewegung"* (a trembling motion) at the speed of light. The frequency is equal to ω_c and the distributed volume of the motion can be interpreted as having dimensions comparable to $\lambda\!\!\!^{-}_c$. Other physicists [21-25] have since proposed variations of the Schrodinger model, also with dimensions on the order of $\lambda\!\!\!^{-}_c$.

The proposed spacetime particle model satisfies the Dirac equation and has both similarities and differences compared to the Schrodinger model. The similarity is that the spacetime wave model has speed of light propagation within a volume with radius $\lambda\!\!\!^{-}_c$ at a frequency of ω_c. The difference is that there is no point particle. Instead a dipole wave in spacetime with quantized angular momentum <u>fills</u> a volume with radius $\lambda\!\!\!^{-}_c$ and undergoes a somewhat chaotic propagation at the speed of light which might be characterized as spacetime "*zitterbewegung".*

4.6 Inertia Test

Previously, we saw that the spacetime particle model passes the test of having the correct energy. When we substituted ω_c, $\lambda\!\!\!^{-}_c$, and A_s into Eq. (5) we obtained $E = kE_i$. However, is it fair to assume that merely because we obtained the correct energy this automatically translates into obtaining the correct inertia (rest mass)? To examine the origin of inertia, we will start with a thought experiment. Suppose that there was a hypothetical box with 100% reflecting internal walls. Any light trapped in such a box is "confined light". A freely propagating photon is a massless particle but what about a confined photon in the 100% reflecting box? Suppose that the box initially contains an electron and a positron. Then after some time these two particles interact and their energy is converted to two confined gamma ray photons. Would there be any difference in the box's total inertia when the energy is in the form of confined particles compared to the same energy in the form of confined photons? If there is any difference, then this would be a violation of the conservation of momentum. This implies that a "confined photon" acquires inertia that is indistinguishable from a particle's inertia even under relativistic conditions.

The mathematical proof that confined light exhibits inertia is available [14] but the concept is easy to explain. Suppose that two mirrors are aligned to form an optical resonant cavity similar to the mirror system used in a laser. If the aligned mirrors were effectively 100% reflective, then it would be possible to have a specific amount of energy in the form of electromagnetic (EM) radiation confined between the two reflectors. Now suppose that the two aligned mirrors are accelerated in a direction parallel to the cavity's optical axis. Then we can designate one mirror as the "front" mirror and one mirror as the "rear" mirror. During the time that it takes for the light to propagate from the front to rear mirror, the optical cavity has some change in velocity. The light striking the rear mirror exerts a slightly larger force on the rear mirror than was exerted on the front mirror. This difference is due to the different Doppler shifted frequencies at the two mirrors. When this force difference is calculated, it exactly equals the inertial force that would be expected for a mass of equal energy. This equivalence extends even to relativistic conditions. In other words, photons are only massless when they are freely propagating. Confined photons have mass.

The model of a spacetime particle has a Planck amplitude wave propagating at the speed of light but circulating within a spherical volume one Compton wavelength in circumference. Even though there are no physical reflectors (other than the surrounding spacetime field), this fermion model meets the criteria of energy propagating at the speed of light but confined to a specific frame of reference. Therefore accelerating the spacetime model of a fermion with internal energy E_i exhibits the same inertial force F as accelerating an equal energy of confined photons. The conservation of momentum requires that there is an exact match between the inertia of a particle and an equal amount of energy in the form of confined photons.

5. Charge, Electric Fields and Black Holes

So far, it has been shown that adopting the assumption that the universe is only spacetime gives new insights into particles and forces. However, if the single building block of everything in the universe is the energetic spacetime field, then the implication is that all of the effects associated with electrical charge, electric fields, etc. should also be able to be explained using only the properties of spacetime. This is a severe test of the starting assumption.

To obtain an insight into the electrical properties of nature, we will express the electrical potential $\mathbb{V}$ (the voltage relative to neutrality) and the electric field $\mathbb{E}$ in dimensionless Planck units because Planck units are fundamentally based on the properties of spacetime. In both cases we will assume Planck charge q_p. Therefore: $\mathbb{V}_E \equiv q_p / 4\pi\varepsilon_o r$ and $\mathbb{E}_E \equiv q_p / 4\pi\varepsilon_o r^2$. Converting these to dimensionless Planck units (underlined) we divide by Planck voltage $\mathbb{V}_p = \sqrt{c^4/4\pi\varepsilon_o G} \approx 10^{27}$ V and Planck electric field $\mathbb{E}_p = \sqrt{c^7/4\pi\varepsilon_o \hbar G^2}$.

$$\underline{\mathbb{V}}_E = \frac{\mathbb{V}_E}{\mathbb{V}_p} = \frac{\sqrt{4\pi\varepsilon_o \hbar c}}{4\pi\varepsilon_o r}\sqrt{\frac{4\pi\varepsilon_o G}{c^4}} = \sqrt{\frac{\hbar G}{c^3}}\frac{1}{r} = \frac{L_p}{r} \qquad (24)$$

$$\underline{\mathbb{E}}_E = \frac{\mathbb{E}_E}{\mathbb{E}_p} = \frac{\sqrt{4\pi\varepsilon_o \hbar c}}{4\pi\varepsilon_o r^2}\sqrt{\frac{4\pi\varepsilon_o \hbar G^2}{c^7}} = \frac{\hbar G}{c^3 r^2} = \frac{L_p^2}{r^2} \qquad (25)$$

What is the physical interpretation of $\underline{\mathbb{V}}_E = L_p / r$ and $\underline{\mathbb{E}}_E = L_p^2 / r^2$? First, an electrical charge only affects the spatial properties of spacetime because there is no time term in Eq. (24, 25). Second, only the radial spatial dimension is affected. Third, the dimensionless ratio L_p / r is proposed to represent the slope of a spatial strain in spacetime. We also know that an electric field is non-reciprocal. A polarized distortion of spacetime is required since there is a difference when we proceed from + to – compared to the opposite direction. Spacetime must exhibit different properties proceeding in opposite directions.

The proposed spacetime based model of an electric field is a polarized (non-reciprocal) distortion of space such that the one-way distance (time of flight) between a positive and negative charge would be slightly different proceeding from + to – compared to the reverse direction. It is not known which direction is shorter. However, the round trip distance should be unchanged. Even though there are some unknowns, we can calculate the magnitude of the effect. To quantify the effect on spacetime produced by a charge, we will define a proposed new constant, designated eta (η). This constant converts units of electrical charge (coulomb) into a polarized strain of space with dimensions of length. This relationship can be extracted from Eq. (24). The validity of this conversion factor will be determined by testing. From Eq. (24) we have:

$$\mathbb{V}_E = \frac{q_p}{4\pi\varepsilon_o r} = \frac{L_p \mathbb{V}_p}{r}$$

$$q_p = \frac{L_p \mathbb{V}_p 4\pi\varepsilon_o r}{r} = L_p\sqrt{\frac{4\pi\varepsilon_o c^4}{G}}$$

$$\eta \equiv \sqrt{\frac{G}{4\pi\varepsilon_o c^4}} = \frac{L_p}{q_p} \approx 8.61\times 10^{-18}\ \text{meter/coulomb} \qquad (26)$$

We will first test the conversion of several constants incorporating electrical charge. These are: elementary charge e, the Coulomb force constant $1/4\pi\varepsilon_o$ (m^3kg/s^2C^2), the magnetic permeability constant $\mu_o/4\pi$ (kg m/C^2), and the impedance of free space Z_o (kg m/sC^2). To eliminate 1/C^2 requires multiplying these constants by $1/\eta^2$. We will also use: $\alpha = e^2/4\pi\varepsilon_o \hbar c$

$$e(\eta) = \sqrt{\alpha 4\pi\varepsilon_o \hbar c}\sqrt{\frac{G}{4\pi\varepsilon_o c^4}} = \sqrt{\frac{\alpha\hbar G}{c^3}} = \sqrt{\alpha}L_p \qquad (27)$$

$$\frac{1}{4\pi\varepsilon_o}\left(\frac{1}{\eta^2}\right) = \left(\frac{1}{4\pi\varepsilon_o}\right)\left(\frac{4\pi\varepsilon_o c^4}{G}\right) = \frac{c^4}{G} = F_p \qquad (28)$$

$$\frac{\mu_o}{4\pi}\left(\frac{1}{\eta^2}\right) = \left(\frac{1}{4\pi\varepsilon_o c^2}\right)\left(\frac{4\pi\varepsilon_o c^4}{G}\right) = \frac{c^2}{G} \qquad (29)$$

$$Z_o\left(\frac{1}{\eta^2}\right) = \left(\frac{1}{\varepsilon_o c}\right)\left(\frac{4\pi\varepsilon_o c^4}{G}\right) = 4\pi\frac{c^3}{G} = 4\pi Z_s \qquad (30)$$

We will perform several tests before commenting. From the above $\mu_o = 4\pi c^2/G$, $\varepsilon_o = G/4\pi c^4$ and $Z_o = 4\pi c^3/G$ When we convert: $c = \sqrt{1/\varepsilon_o\mu_o}$ and $Z_o = \sqrt{\mu_o/\varepsilon_o}$ to the equivalent equations substituting the spacetime conversions, the equations are still correct. Also, we will test the conversion by calculating the force between two electrons (charge *e*) two different ways. Eq. (31) below uses the standard Coulomb law and Eq. (32) uses the spacetime conversions for $1/4\pi\varepsilon_o$ and *e*. They give the same answer.

$$F_e = \frac{e^2}{4\pi\varepsilon_o r^2} = \frac{\alpha\hbar c}{r^2} \qquad (31)$$

$$F_e = \frac{F_p \alpha L_p^2}{r^2} = \frac{c^4}{G}\frac{\alpha}{r^2}\frac{\hbar G}{c^3} = \frac{\alpha\hbar c}{r^2} \qquad (32)$$

In Eq. (28), it is reasonable that the Coulomb force constant $1/4\pi\varepsilon_o$ should convert to Planck force c^4/G. Planck force is the largest force that spacetime can exert. However, the most important revelation is Eq. (30). The impedance of free space ($Z_o = \mathbb{E}/\mathbb{H}$) converts to c^3/G the impedance of spacetime obtained from GR (ignore 4π). Since Z_o converts to Z_s, this implies that EM radiation experiences the same impedance as gravitational waves which propagate in the medium of spacetime. The implication is that photons also are waves propagating in the medium of the spacetime field. Photons are not packets of energy propagating THROUGH the empty void of spacetime. Photons are waves with quantized angular momentum propagating IN the medium of the spacetime field.

If EM radiation propagates in the medium of spacetime, does this mean that spacetime is the new aether? Spacetime does have energy density and c^3/G impedance that permits waves to propagate at the speed of light but there are also important differences compared to the properties attributed to the aether. First, a photon possesses angular momentum which is quarantined by the superfluid spacetime field. This produces quantization of angular momentum. Photons acquire a particle-like property because quantized angular momentum also affects energy. Absorption results in a collapse of waves so that the entire angular momentum and energy are deposited in a single absorbing unit (atom, molecule, etc.). The superfluid spacetime field causes "wave-particle duality".

A second difference between the aether and the spacetime field is that the aether was presumed to have a frame of reference which should have been detected by the Michelson-Morley experiment. The spacetime field is strongly interacting dipole waves propagating at the speed of light. It is not possible to detect motion relative to this medium. For example, ε_o, μ_o and G are properties of the spacetime field and are unchanged in all frames of reference. Also, suppose that it was possible to do a Michelson-Morley experiment using gravitational waves rather than light. Gravitational waves are undeniably propagating in the medium of spacetime and experience impedance of c^3/G. However, gravitational waves are always propagating at the speed of light, from all frames of reference. A Michelson-Morley experiment using gravitational waves would be unable to detect motion relative to the spacetime field. Similarly, if photons are a quantized wave propagating in the spacetime field, they also would be observed to always propagate at the speed of light. The explanation of this paradox is that particles, fields and forces are also spacetime and compensate (Lorentz transformation) to keep the locally measured speed of light constant.

Next we will attempt to quantify the magnitude of the distortion of spacetime produced by photons to see if it is experimentally measurable. To simplify the calculation and maximize the effect, we will imagine confining photons in the smallest possible volume for a given wavelength. Circularly polarized photons can exist in a cylindrical waveguide that is slightly larger than ½ wavelength in diameter and further confined by two flat mirrors perpendicular to the cylindrical axis and separated by ½ wavelength. This forms the smallest possible vacuum resonant cavity which we will call "maximum confinement". The maximum oscillating electric field strength is at the center of the cavity and the electric field is zero at all the surfaces. Even though the cavity is ½ λ long and ½ λ in diameter with nonuniform electric and magnetic fields, a dimensional analysis plausibility calculation can make the simplifying assumption that the excitation (stressed spacetime) is uniform over a volume of $\bar{\lambda}^3$, and zero everywhere else. The energy of n photons is $E = n\hbar\omega$ and the energy density in $\bar{\lambda}^3$ is $U = n\hbar\omega / \bar{\lambda}^3 = n\hbar\omega^4 / c^3$. Combine this with Eq. (4):

$$U = \frac{A^2\omega^2 Z_s}{c} = \frac{n\hbar\omega^4}{c^3}$$

$$A = \sqrt{\left(\frac{n\hbar G}{c^3}\right)\left(\frac{\omega^2}{c^2}\right)} = \frac{\sqrt{n}L_p}{\bar{\lambda}} = \frac{\Delta L}{\bar{\lambda}}$$

$$\Delta L = \sqrt{n}L_p \qquad (33)$$

The indication is that n coherent circularly polarized photons produce an oscillating length change of $\sqrt{n}L_p$ over a distance of $\bar{\lambda}$ if we assume a maximum confinement cavity. This is another prediction. To analyze this, suppose that we have a microwave cavity designed to achieve maximum confinement of a reduced wavelength of $\bar{\lambda} = 0.1$ m. The cavity would be slightly larger than 0.314 m in diameter and the flat reflectors would be separated by 0.314 m. An interferometer with oppositely propagating beams would attempt to detect a polarized path length changed caused by the rotating electric field.

Without attempting to describe the experiment in more detail, it is possible to calculate whether the effect would be large enough to measure. Theoretically it is physically possible to detect length changes larger than Planck length (∼10^{-35} m) [3-7]. However, current interferometer technology such as the LIGO experiment can currently detect modulated length changes in the range of 10^{-18} m. Since $L_p \approx 10^{-35}$ m we would have to have $n \approx 10^{34}$ photons in the maximum confinement cavity to achieve a 10^{-18} m effect. ($\sqrt{10^{34}} \times 10^{-35} m \approx 10^{-18} m$). If we assume a microwave cavity tuned for $\bar{\lambda} = 0.1$ m ($\omega = 3\times10^9$ s^{-1}) the energy of confined microwave photons would have to be about 3×10^9 J. This experiment is beyond current technology.

However, all is not lost. Suppose that we imagine a thought experiment where it is possible to increase the number of the confined photons to any desired level. The spacetime based model of photons predicts that EM radiation should have a maximum intensity limit for a maximum confinement experiment where spacetime is simply not able to transmit a higher intensity. This would occur if the intensity reached the condition which demanded that the spatial displacement of spacetime (*ΔL*) equaled the reduced wavelength $\bar{\lambda}$ of the EM radiation causing the effect. In the case of microwave radiation with a reduced wavelength of 0.1 m, this would occur when $\Delta L = \bar{\lambda} = 0.1$ m. This is demanding 100% modulation of the spacetime volume in the maximum confinement resonant cavity. (ignoring numerical factors near 1).

This theoretical maximum intensity limit will be calculated. The critical number of photons n_c that achieves $\Delta L = \bar{\lambda}$ is $n_c = E_c\bar{\lambda}/\hbar c$ where the critical energy is designated E_c.

$$\Delta L = \sqrt{n_c}L_p = \sqrt{\frac{E_c\bar{\lambda}}{\hbar c}}\sqrt{\frac{\hbar G}{c^3}} \qquad \text{set } \bar{\lambda} = \Delta L$$

$$\Delta L = \frac{GE_c}{c^4} = \frac{Gm_c}{c^2} = R_s \qquad (34)$$

Eq. (34) gives the classical Schwarzschild radius $R_s = Gm_c/c^2$ of a black hole with energy of E_c. It is not necessary to do an experiment! The prediction that there should be a maximum intensity limit is confirmed by GR because the intensity which achieves 100% modulation of spacetime (achieves $\Delta L = \bar{\lambda}$) also forms a black hole which blocks further transmission of EM radiation. For example, assuming a reduced wavelength of 0.1 m, it would take about 10^{68} confined photons (∼10^{43} J) to achieve $\Delta L = \bar{\lambda} \approx 0.1$ m. This energy in this radius achieves a black hole with a classical Schwarzschild radius of 0.1 m. For more information about the spacetime based model of a photon, see a related article titled: *Spacetime-Based Model of EM Radiation* [26].

Another hypothetical experiment would use a cubic vacuum capacitor consisting of two flat and parallel plates, each with dimensions DxD and separated by distance *D*. If the voltage on this capacitor is $\mathbb{V}$, then this voltage in dimensionless Planck units (underlined) would be $\underline{\mathbb{V}} = \mathbb{V}/\mathbb{V}_p$. A time of flight distance measurement across the capacitor would experience a path length difference of ΔL between opposite propagation directions. Using previously stated principles, the polarized strain equation is: $\Delta L = D\underline{\mathbb{V}}$.

Since Planck voltage is about 10^{27} volts, even 10^{6} volts would be $\Delta L \approx 10^{-21} D$ and unmeasurable.

However, $\Delta L = D\underline{\mathbb{V}}$ also predicts that the properties of spacetime specify a maximum possible voltage. At Planck voltage $\underline{\mathbb{V}} = 1$, therefore the distortion is $\Delta L = D$. This is 100% distortion of the volume within the cubic vacuum capacitor. The spacetime model of charge predicts that it should be impossible to exceed this voltage. A calculation similar to Eq. (34) shows that any size cubic vacuum capacitor would form a black hole with radius of $R_s = D$ when the voltage equals Planck voltage. Therefore this is another prediction of the spacetime-based model which is verifiable.

6. Summary and Conclusion

This paper attempts to show that it is plausible for the entire universe to be made of just 4 dimensional spacetime. The key step in this endeavor is that the large energy density of the vacuum implied by quantum electrodynamics and quantum chromodynamics is characterized as a sea of dipole waves in spacetime with spatial displacement amplitude of $\pm L_p$ (Planck length) and temporal displacement amplitude of $\pm T_p$ (Planck time). These undetectable small amplitude waves exist in spacetime which is a medium with impedance of $Z_s = c^3/G \approx 4 \times 10^{35}$ kg/s.

Therefore, the spacetime field is pictured as being a sea of these Planck amplitude waves at all frequencies up to Planck frequency. This achieves a vacuum energy density of about 10^{113} J/m^3 required to explain zero point energy. These waves have no angular momentum and would exhibit superfluid properties. Quantized angular momentum present in spacetime since the Big Bang is proposed to be isolated by the spacetime field into quantized units of $\hbar/2$ which are the fermions.

A model of a fundamental particle (fermion) has been suggested as a rotating dipole wave distortion of the spacetime field. This dipole wave in spacetime is propagating at the speed of light but is confined to a spherical volume one Compton wavelength in circumference. The rotation frequency is equal to the particle's Compton frequency ω_c and the radius is equal to the reduced Compton wavelength $\lambda\!\!\!^{-}_c$. An interaction with the surrounding spacetime field stabilizes this rotating wave.

This fermion model has quantifiable structure such as amplitude, frequency, radius, etc. Therefore it is possible to confirm that this particle model plausibly exhibits a particle's energy, angular momentum, inertia and ability to appear to be a point particle. This proposed model would also create a disturbance in the surrounding spacetime field. The nonlinear portion of the disturbance was shown to have amplitude corresponding to the weak gravity curvature of spacetime. The linear portion is proposed to be associated with the particle's electric field. Also the magnitude of the gravitational force was derived without making an analogy to acceleration. The model makes predictions about the electrostatic and gravitational forces. One prediction is that both forces scale as a fundamental function of $\lambda\!\!\!^{-}_c$. Eq. (17-23) show that dramatic simplifications occur when separation is expressed as N multiples of $\lambda\!\!\!^{-}_c$. A second prediction is that these forces should be related by a simple difference in exponents. Eq. (15 - 21) support this prediction.

Electric and magnetic fields are also proposed to be a distortion of the spacetime field. A charge conversion constant $\eta \equiv L_p/q_p$ was derived with units of meter/coulomb. When this proposed constant is used to convert the Coulomb force constant $1/4\pi\varepsilon_o$, it becomes Planck force c^4/G. Also, the impedance of free space Z_0 becomes the impedance of spacetime $Z_s = c^3/G$. The conclusion is that photons experience the same impedance as gravitational waves and therefore photons are proposed to be quantized waves propagating in the medium of the spacetime field. Another prediction of this model is that EM radiation produces a physical distortion of spacetime that would be measurable if the intensity could be made large enough. The prediction implies that there should be a set of conditions which achieve a maximum intensity limit. This transmission limit is confirmed because this limit corresponds to the condition which makes a black hole. Similarly, the spacetime model predicts that a cubic vacuum capacitor achieves maximum distortion of spacetime at Planck voltage. This limit corresponds to the energy density that forms a black hole. All these factors give a broad base of support for the proposed starting assumption – the universe is only spacetime.

7. References

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