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GENERAL RELATIVITY AND THE ZERO POINT ENERGY

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Abstract

An exploration is made of the stochastic electrodynamic (SED) interpretation of mass and gravity. On this approach, gravity has been shown to originate in the attractive secondary electromagnetic fields emitted by charged point particles jostled by the impacting waves of the Zero Point Energy (ZPE). This exploration finds that the four major predictions of General Relativity can be readily reproduced using the ZPE approach. This is possible since the attractive secondary fields locally increase the strength of the ZPE so that it acts as an equivalent refractive medium in a manner originally suggested by Eddington. It is discovered that this ZPE approach to gravity predicts that the fine structure constant will be marginally greater in gravitational fields. A consideration of problems associated with the cosmological constant leads to a model for the origin of the ZPE linked with processes operating at the inception of the cosmos.

Introduction

Stochastic electrodynamics (SED) is a currently developing branch of physics that is providing new insights into physical phenomena. The basis of this approach to physics is the action of the energy inherent in the vacuum, the Zero Point Energy (ZPE), on subatomic particles. As a result of this approach, SED physics has been successful in describing a number of quantum phenomena and the behaviour of atoms in a manner that is often more intuitive than quantum electrodynamics (QED). It has also developed a theory of gravity that is already unified with the other forces of physics. This approach potentially resolves some problems with General Relativity (GR) which are discussed here, including matters relating to the cosmological constant. In addition, it may also provide reasons why there may have been a significantly higher lightspeed at the inception of the cosmos as Moffat,[1] Albrecht & Magueijo[2] propose, or over the lifetime of the universe as Norman & Setterfield,[3] Troitskii,[4] and Barrow[5] have suggested, and why statistical trends in the behaviour of some atomic constants have been noted.[3] Of particular interest in this context is the fact that, in 1911, Planck predicted the existence of the ZPE and demonstrated that Planck's constant, *h*, was a measure of its strength.[6]

Mass and the Higgs Boson

This new approach also offers solutions to problems associated with mass. Some of these were reviewed by Marcus Chown in the 3rd February 2001 issue of "New Scientist" (pp. 22-25). First, he points out that a whole class of theories which, in attempting to unify the forces of nature, usually treat all subatomic particles as having zero rest-mass. In order for these particles to have mass, the concept of the Higgs boson was introduced. Higgs bosons are postulated to fill space and gather like a cloud around the subatomic particles. The energy in this cloud of Higgs bosons, given by $E = mc^2$, then gives rise to the various subatomic masses depending on how well the Higgs "stick" to the various particles.

However, as Wilczek, of the Massachusetts Institute of Technology, pointed out in the above referenced article in "New Scientist," nobody knows what governs the amount of "sticking." Wilczek also notes that this mechanism *"hardly explains"* the rest mass of ordinary matter like protons and neutrons, which are thought to be composed of "up" and "down" quarks held together by gluons. Since gluons have no rest mass and quarks very little, most of the mass of ordinary matter is meant to come from the "colour field", which is the force that binds quarks and gluons together. Therefore, even when a proton is stationary, energy is said to be residing within it. Wilczek then says *"Whether you call this an explanation of mass is a matter of taste, I guess. I would be inclined to say no, since it doesn't simplify the description of mass, nor suggest testable new properties of mass."* As Bernard Haisch of the California Institute for Physics and Astrophysics states in the same article, *"the Higgs mechanism does not explain why mass, or its energy equivalent, resists motion or reacts to gravity."*

Mass and the Zero-Point Energy

Because of these problems, Haisch and his colleagues are refining an SED alternative. Their published papers can be found at http://www.calphysics.org/sci_articles.html. This work is producing results. They agree, along with quantum pioneers de Broglie and Schroedinger, that subatomic particles such as electrons are actually massless, point-like charges, which they sometimes refer to as partons. Haisch then notes that the vacuum contains energy expressed as the randomly fluctuating electromagnetic fields of the ZPE. These electromagnetic waves impinge upon a charged, point-like particle, causing it to randomly jitter in a manner similar to what we see in Brownian motion. Schroedinger referred to this "jitter motion" by its German equivalent, *Zitterbewegung*. In the usual model, first proposed by Dirac, the fluctuations of this *Zitterbewegung* happen at the speed of light. As de Broglie and Schroedinger pointed out, the result is that *"an electron is actually a point-like charge which jitters about randomly within a certain volume."* ["New Scientist" op.cit.] This causes it to appear as a fuzzy sphere. In this way Haisch explains, *"Random battering by the jittery vacuum smears out the electron."*

He continues by stating that, under these conditions, *"the Higgs might not be needed to explain rest mass at all. The inherent energy in a particle may be a result of its jittering motion. A massless particle may pick up energy from it, hence acquiring what we think of as rest mass."* Hal Puthoff explained it this way in 1989, *"In this view the particle mass* m *is of dynamical origin, originating in parton-motion response to the electromagnetic zero-point fluctuations of the vacuum. It is therefore simply a special case of the general proposition that the internal kinetic energy of a system contributes to the effective mass of that system."* [7] The mathematical calculations support this view.

In a similar way, inertial mass can be accounted for since an electron accelerated through the electromagnetic fields of the vacuum experiences a pressure, a retarding force proportional to the acceleration, from these ambient fields in a way formalised in 1994 by Haisch, Rueda and Puthoff.[8] Furthermore, different resonant frequencies of different particles result in different masses. This occurs because

"Photons in the quantum vacuum with the same frequency as the jitter are much more likely to bounce off a particle…Higher resonance frequencies ... probably mean a greater mass, as there are more high frequency vacuum photons to bounce off." [6]

In a question and answer segment of the above-referenced website run by Haisch and his colleagues at the California Institute for Physics & Astrophysics, they elaborate that

"the kinetic energy associated with the ZPF-driven Zitterbewegung is what provides the energy for the $E = mc^2$ *relation. The real stuff is the energy, E, and as with inertial mass, it is only our (obstinate) habit of believing that matter must possess mass that leads to our insisting that there must exist a right hand side to this equation, namely* mc^2*. In reality (perhaps) there is no mass, just the energy, E, that the quantum vacuum gives in the form of Zitterbewegung in the same way that there is no inertial mass, just the force that the quantum vacuum gives when an object accelerates."*

A Problem With General Relativity

In a similar fashion to that pertaining to mass, it is commonly assumed that GR has explained all gravitational phenomena and has provided a framework within which basic cosmological questions may be answered. However, GR does not accommodate the possibility of a variable speed of light (VSL) nor does it resolve the issue of statistical trends in atomic constants, including Planck's constant, *h*. Furthermore, while it may be correct to state that GR is a good representation of reality, that is not the same as explaining how all gravitational forces originate. This problem was mentioned in 2002 in *Pushing Gravity,* edited by Matthew R. Edwards [Apeiron] and described as follows:

"In the geometric interpretation of gravity, a source mass curves the 'space-time' around it, causing bodies to follow that curvature in preference to following straight lines through space. This is often described by using the 'rubber sheet' analogy ... However, it is not widely appreciated that this is a purely mathematical model, lacking a physical mechanism to initiate motion. For example, if a 'space-time manifold' (like the rubber sheet) exists near a source mass, why would a small particle placed at rest in that manifold (on the rubber sheet) begin to move towards the source mass? Indeed, why would curvature of the manifold (rubber sheet) even have a sense of 'down' unless some force such as gravity already existed? Logically, the small particle at rest on a curved manifold would have no reason to end its rest unless a force acted on it. However successful this geometric interpretation may be as a mathematical model, it lacks physics and a causal mechanism." [p. 94]

Others have also noticed this particular problem. For example, Haisch and his colleagues at the California Institute for Physics and Astrophysics present the situation like this:

"The mathematical formulation of GR represents spacetime as curved due to the presence of matter and is called geometrodynamics because it explains the dynamics (motions) of objects in terms of four-dimensional geometry. Here is the crucial point that is not widely understood: Geometrodynamics merely tells you what path (called a geodesic) that a freely moving object will follow. But if you constrain an object to follow some different path (or not to move at all) geometrodynamics does not tell you how or why a force arises. ... Logically you wind up having to assume that a force arises because when you deviate from a geodesic you are accelerating, but that is exactly what you are trying to explain in the first place: Why does a force arise when you accelerate? ... this merely takes us in a logical full circle." [10]

The required explanation for the origin of gravitation given by the CIPA team elucidates the earlier points that have been made here. They begin by noting that in 1968, Russian physicist Andrei Sakharov linked gravitation and inertia with the Zero Point Fields (ZPF). In 1989, Puthoff formulated this into a quantifiable theory of gravitation. Later, Haisch and Rueda developed this further. They noted that all charges in the universe undergo the Zitterbewegung jostling through interaction with the ZPF. These fluctuations are relativistic so that the charges move at velocities close to that of light. Haisch, Rueda and Puthoff explain further:

"Now a basic result from classical electrodynamics is that a fluctuating charge emits an electromagnetic radiation field. The result is that all charges in the universe will emit secondary electromagnetic fields in response to their interactions with the primary field, the ZPF. The secondary electromagnetic fields turn out to have a remarkable property. Between any two [charged] particles they give rise to an attractive force. The force is much weaker than the ordinary attractive or repulsive forces between two stationary electric charges, and is always attractive, whether the charges are positive or negative. The result is that the secondary fields give rise to an attractive force we propose may be identified with gravity. ... Since the gravitational force is caused by the trembling motion, there is no need to speak any longer of a gravitational mass as the source of gravitation. The source of gravitation is the driven motion of a charge, not the attractive power of the thing physicists are used to thinking of as mass." [11]

In fact, Haisch summarised this in 2001 in the "New Scientist" article quoted above when he said, *"This might explain why gravity is so weak. One mass does not pull directly on another mass but only through the intermediary of the vacuum."* On this basis, then, gravitation and mass may be considered to be simply manifestations of electromagnetic energy which is directly linked with the ZPE.

A Different Explanation for Relativistic Effects

But it is now possible to take this picture one stage further based on comments originally made by Sir Arthur Eddington. In 1920 he stated

"Light moves more slowly in a material medium than in a vacuum, the velocity being inversely proportional to the refractive index of the medium. The phenomenon of refraction is in fact caused by the slewing of the wave-front in passing into a region of

smaller velocity. We can thus imitate the gravitational effect on light precisely, if we imagine the space round the sun filled with a refracting medium which gives the appropriate velocity of light. To give the velocity c(1-2μ/r), the refractive index must be 1/(1-2μ/r)…Any problem on the paths of rays near the sun can now be solved by the methods of geometrical optics applied to the equivalent refracting medium. It is not difficult to show that the total deflection of a ray passing at a distance r from the centre of the sun is [twice] the deflection of the same ray calculated on the Newtonian theory [a result which accords with] Einstein's theory." [12]

Since then, others have discussed this proposal. De Felice mentioned nine authors who have looked at this similarity and points out that Einstein himself also suggested the idea that gravitation is equivalent to an optical medium[13]. In fact, Hayden of the University of Connecticut (Physics) pointed out that the general relativistic results of the bending of starlight in the gravitational field of the Sun can be derived, and derived exactly, by this method *"with a few lines of high school algebra"* [see the full statement at the following site: http://www.ldolphin.org/vanFlandern/].

If this approach, outlined by Eddington, Einstein and others, is followed through, the mathematical results obtained by General Relativity would be the same as if the physical vacuum was considered to be an optical medium whose density increased towards any massive object, just as a gravitational field does. The mathematical result of the bending of light by this refractive medium would then be identical to the standard GR approach to a gravitational field in which Einstein's curvature tensor is interpreted to indicate the curvature of space-time. This alternative approach requires three things: First, there must be a key property of the physical vacuum that increases in density in the vicinity of massive objects. Second, this vacuum property must mimic the behaviour of the gravitational field strength, which is proportional to the inverse square of the distance from any massive object. That also implies this property must mimic the behaviour of the gravitational potential, μ/r, in Eddington's approach above, and so be proportional to $1/r$ where r is the distance from the massive body. Finally, this property of the vacuum must affect the speed of light in an inverse fashion in a way similar to a refractive medium. Let us examine these points.

First, this behaviour of the vacuum in the vicinity of massive bodies is in accord with the picture of the vacuum that Haisch, Puthoff and their colleagues present. As noted above, the all-pervasive ZPE has its density increased towards massive bodies by the (attractive) secondary fields emitted by the oscillating point-like charges that comprise matter. The more oscillating charges there are, the more secondary fields there are and hence the greater the total energy density of the ZPE in the vicinity of those charges. This increase in the total energy density of the ZPE towards any massive object can thereby be shown to meet the first requirement for Eddington's alternative model. Second, the strength of these electromagnetic fields is proportional to the inverse square of the distance from their origin. Furthermore, their potential falls off inversely as the distance from the massive body, so changes in the density of the ZPE medium mimics a gravitational potential. Therefore the second set of requirements is also fulfilled. The final condition requires the speed of light to slow down as the strength of the ZPE increases. This was shown to be the case by an article in the *Journal of Theoretics* entitled 'Exploring the Vacuum' found at http://www.journaloftheoretics.com/Links/Papers/Setterfield.pdf.[14] This paper shows there is an inverse relationship between the energy density of the ZPE and the speed of light, provided that the amplitudes of the individual waves making up the ZPE remain unchanged. Since Eddington noted that *"the velocity [of light is] inversely proportional to the refractive index of the medium"*, this result means that the ZPE is behaving in the same way as his "*equivalent refractive medium"* requires. This result can be justified here as follows:

Bending and Slowing of Light in a Gravitational Field

Let us take U_o as the present energy density of the vacuum ZPE away from massive objects and U as the (greater) energy density of the ZPE in the vicinity of such objects. It is found that the results Eddington outlined can be obtained precisely if the effects of the ZPE as an equivalent refractive medium are expressed by a factor, A, such that

$$U_o/U = A^2 \tag{1}$$

In this segment of the paper we are primarily considering situations where $0 < A \leq 1$. That is, we are considering local variations in the ZPE near massive bodies. However, we will later address the situation where there may be cosmological variations in the ZPE. In that case, the factor A may potentially vary from 1 up to infinity.

Changes in the energy density of the ZPE and resultant changes in lightspeed, c, require that the electrical permittivity, ε, and magnetic permeability, μ, of the vacuum are also changing. However, in all such changes in these vacuum properties, it is required that the vacuum remain a non-dispersive medium, otherwise photographs of distant astronomical objects would appear blurred. In turn, this means that the ratio of electric energy to the magnetic energy in a wave remains constant. In other words, the intrinsic impedance of free space, Ω, will remain invariant with these changes. It therefore follows from the definition of the intrinsic impedance of space that[15]

$$\Omega = \sqrt{(\mu/\varepsilon)} = \text{invariant} = \mu c = 1/(\varepsilon c) \tag{2}$$

so that with all the changes being considered throughout this paper Ω will always bear the value of 376.7 ohms. From (2) it can also be discerned that with all these changes, lightspeed must vary in inverse proportion to both the permittivity and permeability of free space. Now, classically, the energy density of an electromagnetic field is given by U, with E and H being the electric and magnetic intensity of the waves, which is proportional to their amplitude. The standard equation then reads:[16]

$$U = ½ (\varepsilon E^2 + \mu H^2) \quad \text{so that} \quad 2U = (\varepsilon E^2 + \mu H^2) \tag{3}$$

If U is now taken to refer specifically to the energy density of the vacuum ZPE, and the amplitudes of the electromagnetic waves making up the ZPE remain unchanged, then both E and H will also remain unchanged as the strength of the ZPE varies. This then means that as the strength of the ZPE varies, so does the vacuum permittivity and permeability such that

$$U \propto \varepsilon \propto \mu \propto 1/c \tag{4}$$

where the symbol $\propto$ means "proportional to" throughout this paper. The last step in (4) follows from the basic equation $c^2 = 1/(\varepsilon\mu)$. As a result of (4), we can now use equation (1) to obtain the result that

$$A^2 = U_o/U = \varepsilon_o/\varepsilon = \mu_o/\mu = c/c_o \tag{5}$$

which means that

$$c = c_o A^2 \tag{6}$$

Two other identities need also to be established before we continue. With changes in lightspeed, *c*, as noted in (6), it is required that energy be conserved. This means that, from Einstein's relation $E = mc^2$, energy *E* is being conserved there also. This necessarily means that for all atomic particle masses, *m*, we have the proportionality

$$m \propto 1/c^2 \tag{7}$$

On the basis of (1), (6) and (7) it follows that

$$m = m_o/A^4 \tag{8}$$

where m_o is the current accepted value of atomic masses. Equations (7) and (8) can be shown to be true in all circumstances where a varying ZPE is being considered since atomic particle masses are dependent upon the strength of the ZPE on the SED approach. Because gravity is a ZPE phenomenon as well as mass, the Newtonian gravitational constant *G* is also dependent upon the strength of the ZPE. The form of that dependence may be found by an inspection of the units of *G*, namely [meters^3/(kilogram-seconds^2)]. These units reveal that mass (kilograms) appears on the denominator. Consequently, we can write from (8) that for all changes in the ZPE

$$m_o/m = A^4 = G/G_o \tag{9}$$

This also means that the product

$$Gm = (G_o A^4)(m_o/A^4) = G_o m_o = \text{invariant} \tag{10}$$

However, the one condition that now needs to be fulfilled is that Eddington's factor

$$(1-2\mu/r) \propto A^2 \tag{11}$$

When this condition holds, and the preamble to equation (17) below shows that it does, then the result that Eddington obtained for the bending of light in a gravitational field is applicable here also. As a consequence, the GR prediction of the bending of light in a gravitational field can be reproduced precisely by the mechanism of the increased energy density of the ZPE in the vicinity of massive objects.

Associated with this GR prediction was another prediction that was verified during the 1960's, namely the slowing of radar signals passing through the Sun's gravitational field. Irwin Shapiro confirmed this by analysing radar signal returns from both Venus and Mercury.[17] This latter result follows directly from (6) and (11) above and is the flip side of the effects of a refractive medium bending light in a gravitational field. It necessarily follows that if the density of the ZPE increases in the vicinity of a massive object, then as equation (6) and reference [11] show, lightspeed (and hence radar signals) must also slow as an inevitable result. This simultaneous slowing and bending of light in the vicinity of massive objects are therefore twin results from an increased density of the ZPE.

However, the bending and slowing of light in a gravitational field were only two of the basic observational proofs of GR. Einstein also proposed that atomic clocks would be slowed in a gravitational field, and finally gave an explanation for the anomalous behaviour of the planet Mercury in its orbit. Let us examine the problem of Mercury's behaviour next.

The Basic Formula for Orbit Perihelion Motion

For all orbits that are essentially elliptical, the basic formula for the motion of the orbit perihelion is always the same since it is governed by the properties of motion of an astronomical body in an ellipse. Van Flandern, who was an astronomer with the US Naval Observatory in Washington, noted in 1999 that

> *"Perturbations that are themselves modulated by the size and shape of the elliptical orbit and by the speed of a body travelling along that ellipse generally change the perihelion motion by simple integer multiples of the basic form...The nature of this basic form is such that parameter-free perturbations are mostly constrained to produce perihelion motions that are integer (or at worst, half-integer) multiples of it …This basic form is:*
>
> $$N = n\mu/[c^2a(1-e^2)] \qquad (12)$$
>
> *Where $n = 2\pi/P$ is the orbital mean motion of the planet, P is its orbital period,* μ *is the product of the gravitational constant and the mass of the Sun, a is the semi-major axis (mean distance) of the orbit, e is orbital eccentricity, and c = speed of light…The observed perihelion advance for Mercury is three multiples of the basic form, 3N, to within the error of observations.*
>
> *In GR, the correct multiplier of N is arrived at by combining three contributions. The first is the effect of 'time dilation', which contributes +4N. The second is the effect of 'space contraction', which contributes –2N. The third is the effect of*

mass or momentum increase with speed, which contributes +1 N. The sum of these three contributions gives the observed amount +3N ... It is curious that Einstein required a combination of three effects, with one of them cancelling 40% of the contribution of the other two." [18]

An Alternative Approach

By comparison with Einstein's formulation, any approach using the ZPE has less room for manoeuvre. There is no 'time dilation' or 'space contraction' which would affect perihelion motion. Furthermore, equation (12) reveals that there can be no contribution to *N* that results from any change in mass or change in momentum of the orbiting body, since that quantity does not enter the equation. This situation is in stark contrast to Einstein's less constrained approach. Nevertheless, on a qualitative basis it is possible to discern the outline of an answer from a suggestion first made in 1999 that appeared in the collection of the "Pushing Gravity" symposium papers of 2002.[19]

The symposium noted that if perchance the planets were immersed in a medium that increased in density towards the Sun, then

"the elliptical motion of orbiting bodies is slowed most by [the medium] at perihelion, where that medium is densest, and slowed least at aphelion, where [the medium] is sparsest. This velocity imbalance (relatively slower at perihelion, relatively faster at aphelion) rotates the ellipse forward, which is what an advance of perihelion means."

This article indicated that if there was a Newtonian velocity slowing factor $1/\gamma^2$ for a massless body with actual orbital velocity v, when v_n is the equivalent velocity under Newtonian style forces, then the velocity of the orbiting body can be shown to be given by

$$v = v_n/\gamma^2 \tag{13}$$

where, $\gamma \geq 1$. It was shown in the above article that this situation produced the required perihelion advance with the $1/\gamma^2$ slowing factor due to the velocity imbalance caused by the varying density of the medium. This approach using a single factor reproduces exactly the observed perihelion advance, as shown below, without the messy juggling of three factors that GR requires.

The immediate problem is that, although the energy density of the ZPE increases towards the Sun (or any massive body), just as the above analysis requires, a planet in orbit might not be expected to experience an imbalance of the Newtonian velocity as a result of changes in the density of the ZPE that permeates the physical vacuum. However, the subatomic particles making up all matter would definitely be affected by these ZPE changes. And therein can be found the basis of an answer which is in full accord with the whole ZPE model.

Matter and Waves

In 1926, de Broglie pointed out that every subatomic particle has the properties of a wave. This can mean that all matter may be considered to be a collection of waves. Thus the planets orbiting through a vacuum may be considered to be a collection of matter waves propagating through the ZPE. The increase in energy density of the ZPE in the vicinity of the Sun will therefore have its effects on the collection of waves that comprise each planet as they orbit the Sun. As these waves move through the denser (or sparser) ZPE, this slows down (or speeds up) the motion of the entire collection of waves that make up the orbiting planet. If a particle moves through the ZPE with a velocity, v, it can be shown that v is also the group velocity of the matter wave.[20] Therefore, a collection of particles, such as a planet, made up of their wave equivalents would also propagate through the ZPE with a velocity v under ordinary circumstances. However, the increase in the energy density of the ZPE slows the propagation speed of the matter waves in a manner inversely proportional to the energy density. As a result, the velocity of the particles making up those waves must also slow since the group velocity of the waves and the particle velocity must remain synchronised, as French points out. Therefore, if the expected velocity was the Newtonian velocity, v_n, and the actual velocity is v, then the slowing factor is given by the ratio v/v_n which is proportional to the ratio of the ZPE energy density U/U_o. This can be written as

$$v/v_n = U_o/U = A^2 \qquad \text{therefore} \qquad v = v_n A^2 \tag{14}$$

But (14) has the same form as (13) which gave the necessary solution to the problem provided we make the identification that the slowing factor

$$A^2 = 1/\gamma^2 \tag{15}$$

This then leads to the required solution in a way outlined by Van Flandern and which is reproduced here with the pertinent amendments and additions.[21]

Reproducing the Perihelion Advance Formula

The added slowing and speeding up of an orbiting body due to the variation in A stimulates an extra force acting on the body along the velocity vector. The formula for the change in Newtonian velocity is

$$\delta v = v - v_n = v_n(A^2 - 1) \tag{16}$$

which follows from (14). However, in the proportionality given in (11) the term μ/r is Eddington's gravitational potential. This involves the product Gm, which, as shown in (10) is invariant. Now for an orbiting planet the quantity[22] Gm/r^2 is equal to v^2/r. Therefore, Gm/r is proportional to v^2. We can therefore substitute v^2 for Gm/r in the expression for A^2 and obtain the information that

$$(1-2Gm/rc^2) = (1-2\mu/rc^2) \propto A^2 \propto (1 - v^2/c^2) \tag{17}$$

Therefore, if the results from (17) are substituted in the expression in (16) we obtain

$$\delta v = v_n(A^2 - 1) \propto v_n(1 - v^2/c^2\text{-}1) = v_n(- v^2/c^2) \quad (18)$$

If we now take the time derivative of δv, it will give us the extra acceleration needed to produce the required velocity changes. Let us denote this tangential acceleration of the orbiting body by the quantity *T*. This will allow us to compute the perturbing quantity *T*, which can then be introduced into the relevant celestial mechanics formulas to discover what effect it has on the motion of a body in an elliptical orbit.

Therefore if we differentiate δv with respect to time we get an expression for *T*. If we further make v^2 the chief variable rather than *v*, we obtain

$$T = (d/dt)\, \delta v = (d/dt)\, (-v_n v^2/c^2) \quad (19)$$

Since we are interested in the primary results from (19), it is not necessary to make a distinction between *v* and v_n since that would only lead to higher order terms with diminishing effects. Performing the necessary operations then leads to the result that

$$T = - 3v/(2c^2)(dv^2/dt) \quad (20)$$

In order to make it easier to deal with this derivative, we can substitute from the energy equation for elliptical orbits that gives,

$$v^2 = \mu\, [(2/r) - (1/a)] \quad (21)$$

With this information in (21), the derivative can be seen to be

$$dv^2/dt = - (2\mu/r^2)(dr/dt) \quad (22)$$

We now need to determine the new derivative for *r*. This can be found in *Fundamentals of Celestial Mechanics* 2nd edition by J. M. A. Danby (Willmann-Bell, Richmond, 1988). The first equation is (6.2.10) which gives a necessary definition, and the equation that is relevant to our purpose here is his equation (6.3.21) which states that

$$dr/dt = e \sin f\ \sqrt{\{\mu/[a(1-e^2)]\}} \quad (23)$$

where *f* is the orbital true anomaly (the angle at the Sun between the perihelion and the orbiting body). Making all these substitutions, we obtain the final expression for *T*:

$$T = (3\, \mu^{3/2}\, ev / \{c^2 r^2 \sqrt{[a(1-e^2)]}\}) \sin f \quad (24)$$

Danby's equations (11.7.2) and (11.7.4) show that perturbations of the semi-major axis, *a*, and eccentricity, *e*, are purely periodic, and therefore always remain of small amplitude. But Danby's equation (11.7.3) also shows that the perihelion motion contains both small periodic and ever-increasing secular contributions. Applying that equation, where his ω is the longitude of the perihelion, and substituting for *T*, we obtain

$$d\omega/dt = [2\sin f/(ev)]T = (6\,\mu^{3/2} / \{c^2r^2\sqrt{[a(1-e^2)]}\})\,\sin^2 f \qquad (25)$$

The periodic part gives rise to only small periodic variations that can be neglected here. The secular variation, which is of interest here because it builds progressively with time, comes from the time average value of $\sin^2 f/r^2$. Time averages over elliptical motion can be found by integrating over one revolution. Using *dr/dt* from (23) coupled with *df/dt* from Danby's equation (6.3.3), we discover that the required time average is given by the expression $1/[2a^2\sqrt{(1-e^2)}]$. If the orbit was circular, the average of $\sin^2 f = 1/2$, while the average of $1/r^2 = 1/a^2$. If we deal with elliptical orbits, the additional dependence on eccentricity becomes relevant. If we now substitute these results back into (25) and simplify by using Kepler's law for elliptical motion that states that $\mu = n^2a^3$, we arrive at the final formula for perihelion motion, namely that the secular change in perihelion longitude is given by

$$d\omega/dt = 3n\mu/[c^2a(1-e^2)] = 3N \qquad (26)$$

The final equality of *3N* comes from (12), which is equivalent to Danby's equation (4.5.7) and agrees with the GR prediction. When the numerical values of the various parameters are inserted in (26) the quantity *3N* equals 42.98" per century, well within the 1% error mentioned earlier.[15] However, this present result comes solely from the slowing factor presented here and can be derived exactly. By contrast, the GR result comes from juggling three different components using Riemannian geometry and elaborate tensor calculus. Under these circumstances, it appears that the predictions of GR can be reproduced more cleanly by considering a scenario based on the action of the ZPE.

The Slowing of Atomic Clocks

The fourth GR prediction is that atomic clocks would be slowed in a gravitational field. This has been experimentally verified by the Global Positioning System which reveals that atomic frequencies do lessen in the earth's gravitational field. In order to develop this line of thought, we must examine the effects on atomic processes of the secondary fields which locally augment the strength of the ZPE and give rise to gravitational fields. In this instance, we use the Bohr atom for our initial consideration, since, as Eisberg pointed out, it *"is still often employed as a first approximation ... capable of giving numerically correct results with mathematical procedures which are considerably less complicated ... [and] is often helpful in visualising [atomic] processes ..."* [23]

On this basis, then, we note that for equilibrium in its orbit, the motion of electron is balanced by the attraction of the charge on the proton such that, as shown by French,[24]

$$m\omega^2 r = e^2/(\varepsilon r^2) \qquad \text{therefore} \qquad \omega^2 = e^2/(\varepsilon m r^3) \qquad (27)$$

Here, *m* is the atomic mass of the electron, which behaves in a manner given by (8), *r* is the radius of the electron's orbit, which does not change, and ω in this case is the electron's angular velocity. The quantity *e* is the electronic charge and ε is the permittivity of the vacuum. Observations out to the frontiers of the cosmos indicate that cosmological changes in the ZPE maintain the quantity e^2/ε as constant. This means that, cosmologically, $e^2/\varepsilon = e_o^2/\varepsilon_o$. However, to achieve results that accord with observation, it is required that, in a gravitational field

$$e^2/\varepsilon = [e_o^2/\varepsilon_o][1/A^2] \tag{28}$$

This requirement to obtain the correct results allows a prediction to be made which is amenable to an observational test that will be mentioned shortly. This prediction is different from those of GR and may allow a decision to be made as to whether GR or the ZPE approach is correct. The reason for the different behaviour of the e^2/ε ratio in a gravitational field compared with cosmological changes is elucidated below.

On the basis of (8) and (28) we can therefore write from (27) that

$$\omega^2 = [e_o^2/\varepsilon_o][1/A^2](A^4/m_o)(1/r^3)] = \omega_o^2 A^2 \qquad \text{therefore} \qquad \omega = \omega_o A \tag{29}$$

As a consequence, the electron's angular velocity slows by the factor *A*, which means that orbital frequency, $f = \omega/(2\pi)$ also behaves as

$$f = f_o A \tag{30}$$

Since atomic particle movements determine the rate of atomic processes, then (29) and (30) indicate that atomic processes slow by a factor of *A* in what we call a gravitational field. In addition, the run rate of atomic clocks is directly proportional to the frequency of atomic processes. As a result, it can be demonstrated that all atomic frequencies, and therefore atomic clocks, will slow in accord with (29) and (30). Alternatively, it can be stated with equal correctness that the time period, *t*, between ticks on atomic clocks in these circumstances is lengthened in a way that it is given by

$$t = t_o/A \tag{31}$$

In other words, atomic clocks will slow in a manner equivalent to that predicted by GR. These results have been demonstrated as being correct by the GPS clocks. The fourth prediction of GR can thereby be simply accounted for on this new basis that requires equation (28) to hold in a gravitational field.

Lowering of Emitted Frequencies

As noted above, the gravitational field that the clock is immersed in is due to the attractive properties of the secondary electromagnetic radiation emitted by oscillating charges that make up matter. The more charges there are to oscillate, the more secondary radiation will be emitted, and hence the greater the energy density of the ZPE in that vicinity. This local increase in the energy density of the ZPE will cause a drop in the orbital frequency of subatomic particles. In this context, it is important to note that French has shown the frequency of light emitted from an atom is directly proportional to the frequency of revolution of the electron in its orbit. In the case where the electron drops into the lowest orbit in the hydrogen atom from the next orbit out, then the frequency of light emitted corresponds exactly with the frequency of revolution in the lowest orbit.[25] Therefore, the behaviour of the frequency of atomic processes as given in (29) and (30) is also the behaviour of the frequency of light emitted by those processes.

When (30) is applied to light frequencies in this way, it may be discerned that light in a gravitational field is emitted with an intrinsically lower frequency than that in free space.

Planck's Constant and the ZPE

As has already been alluded to above, Max Planck published his 'second theory' in 1911, in which he predicted the presence of the ZPE and simultaneously indicated that the quantity *h* was a measure of the strength of the ZPE.[6] Under these conditions, and bearing in mind equation (1), we can write

$$h/h_o = U/U_o = 1/A^2 \qquad \text{therefore} \qquad h = h_o/A^2 \qquad (32)$$

As the strength of the ZPE increases due to the secondary radiation emitted by the oscillating charged particles that gives rise to the gravitational field, equation (32) will also apply directly in that case.

Some cosmological implications arise when equation (32), describing the behaviour of Planck's constant *h*, is combined with (6). This process yields the result that

$$hc = (h_o/A^2)(c_oA^2) = h_oc_o = \text{invariant} \qquad (33)$$

both cosmologically and in a gravitational field. This situation arises because any local or cosmological variation in the strength of the ZPE will result in a proportional variation in *h*, according to Planck's assessment of the physics of the situation. Furthermore, equations (1) and (6) indicate that any local or cosmological variation in the ZPE will produce an inversely proportional change in lightspeed. The invariance of *hc* cosmologically receives support from astronomical observations. A variety of such observations is listed by Paul Wesson, with an accuracy of 1 part in 100,000 being attained by some.[26]

The Fine Structure Constant

On the basis of this invariance of both the product *hc* and the ratio e^2/ε cosmologically, it is usually thought that the fine structure constant, α, might also be invariant under all conditions as well. However, this has recently been called into question by observations at the frontiers of the cosmos. This quantity was suspected as varying as a result of measurements made by John Webb and his associates.[27] Attention has been drawn to this issue by Davies and his colleagues.[28] Davies has suggested that varying lightspeed may the culprit. On the basis of (32) this may be considered doubtful. Indeed, Carlip and Vaidya also dispute that interpretation, but on different grounds, and instead propose that a change in the electronic charge, *e*, would bring about the observed lowering of the measured value of α. Carlip and Vaidya may have a valid point.[29]

Nevertheless, in order to see the full range of options available on this matter, we need to examine the formula for α. The fine structure constant, α, is defined as[30]

$$\alpha = e^2/(2\varepsilon hc) = e^2/(2\varepsilon h_o c_o) \quad (34)$$

Since both hc and h_oc_o are invariant from (33), the only possibility for variation in α in (34) comes from the behaviour of the ratio e^2/ε. As noted above, this ratio seems to be constant cosmologically, but the specific prediction here is that it should vary in a gravitational field such that from (28) we can write

$$\alpha = e^2/(2\varepsilon hc) = e_o^2/(2\varepsilon_o A^2 h_o c_o) = \alpha_o/A^2 \quad (35)$$

Therefore, in a gravitational field, the value of the fine structure constant is expected to be marginally higher than in an area away from such fields. This may be an answer to the previously discrepant observations by Webb et al.[27] If this is borne out in other gravitational fields, then this would favour the ZPE approach over General Relativity.

Examining the Behaviour of e^2/ε

The data require that the ratio e^2/ε remains constant in the case of a cosmologically increasing ZPE, whereas the ratio is proportional to $1/A^2$ in the secondary fields. A reason for this behaviour may be found by considering the classical electron radius R_e, which is related to the Compton radius of the electron via the fine structure constant. These quantities are significant since they all depend on the strength of the ZPE.

Using the SED approach, Haisch, Rueda, & Puthoff pointed out that *"one defensible interpretation is that the electron really is a point-like entity, smeared out to its quantum dimensions by the ZPF fluctuations."* [32] MacGregor also agreed that this "smearing out" of the electronic charge by the ZPF involved both the *Zitterbewegung* and vacuum polarisation.[65] Haisch, Rueda & Puthoff did the calculations using these phenomena and obtained the Compton radius for the electron as a result. Boyer also did extensive work using this approach. His conclusion was quoted in *The Enigmatic Electron*, namely that *"the quantum zero-point force also expands the sphere."* [33]

As a consequence, if the energy density of the ZPF increased, the "point-like entity" of the electron would be "smeared out" even more and appear larger since the *Zitterbewegung* would be more energetic, and vacuum polarization around charges would be more extensive. Therefore, the spherical electron's apparent radius would be expected to increase in a manner proportional to any ZPE increase. The problem involving the electron radius was discussed at some length by MacGregor who lists some seven options.[33] Let us examine the classical electron radius R_e which is given by French as[34]

$$R_e = e^2/(\varepsilon mc^2) \quad (36)$$

In both the cosmological and the gravitational case, mc^2 is a constant and so may be ignored in this discussion. This then means that R_e is related to e^2/ε. Cosmologically, e^2/ε is constant because the charge and permittivity are perfectly balanced. The expansive effect of an increasing ZPE is offset by the increase in vacuum permittivity so there is no additional force tending to expand the sphere. This balance maintains both e^2/ε and R_e constant so that α also remains constant cosmologically.

However, in the case of the secondary (gravitational) fields, there appears to be an anomalous increase in R_e such that from (28) we can write

$$e^2/\varepsilon = [e_o^2/\varepsilon_o][1/A^2] \propto R_e = R_o/A^2 \qquad (37)$$

Equation (37) reveals that the secondary fields expand the radius of the point-like sphere over and above its equilibrium position and so increase α in a gravitational field.

Statistical Trends in Atomic Constants

The variation in α in a gravitational field introduces the fact that statistical trends imply that several other atomic constants have varied in a way pertinent to this paper. For example, the officially declared values of Planck's constant have increased with time. This trend in the declared values of *h* is graphed in the second graph linked here. In 1965, J. H. Sanders, in *The Fundamental Atomic Constants* [Oxford University Press, p.13] noted that the increasing value of *h* can only partly be accounted for by improvements in instrumental resolution and changes in listed values of other constants. It is quantitatively inadequate to blame the increase in *h* on these factors. At face value, this suggests that the strength of the ZPE has increased with time, since *h* is a measure of this quantity.

But this is not the only evidence. The measured values of lightspeed, *c*, have shown a systematic decrease with time. It was a topic of discussion by important physicists in key journals that ranged from Newcomb's article in *Nature* on 13th May 1886 [pp. 29-32] to that of Birge in 1941 in *Reports on Progress in Physics* [Vol. 8, pages 90-101]. Equation (5) requires that a decrease in c also means a cosmological increase in the strength of the ZPE. An increasing ZPE is also supported by officially declared values of electron rest mass, *m*, which have increased with time. (Graphs of all three quantities are linked here).

These statistical trends in the atomic constants and the 638 measurements by 41 methods upon which they are based were documented in August of 1987 in a Report for Stanford Research Institute International by Norman and Setterfield.[3] The data trends were confirmed in 1993 with an independent statistical examination by Montgomery and Dolphin.[35] This present paper suggests that these data all point to the conclusion that the strength of the ZPE has been increasing with time cosmologically. If this is so, then the quantity *A* in equations (1), (5), (6), (8), (9), and (32) must have been increasingly higher the further back into the past we go. Thus $1 \leq A < \infty$ on a cosmological basis, while in gravitational fields $0 < A \leq 1$. An increase in the ZPE with time is also indicated when problems with the cosmological constant are considered.

The Cosmological Constant

The cosmological constant, Λ, is an important feature of Einstein's equations since his equations needed it to maintain a static universe that was stable against gravitational collapse. It may be helpful to mention that Narliker and Arp have shown that a static, matter-filled universe will remain stable and not collapse.[36] The only condition that their field equations demand for this stability is that particle (atomic) masses increase with time, which is the case in this paper. Under these conditions, the necessity for a cosmological constant disappears even in static Einsteinian universes. Nevertheless, Λ is currently in vogue again to overcome the problem caused by the break-down in the redshift/distance relationship around redshifts from about 0.9 to 2.0. However, in the matters under discussion here, Λ has some relevance to the ZPE and its effects.

It should be noted that there is a basic difference between GR and the SED approach to the cosmological constant. Even though the effect of the ZPE on charged point particles results in the secondary fields we call gravity, it must be remembered that, on the SED approach, the ZPE does not gravitate in and of itself. Neither can it give rise to Λ. However, this is not the case in Quantum Electro-Dynamic (QED) theory, since QED theory often links the ZPE with Λ. A similar situation also applies to GR. This arises because, in GR, the properties of the physical vacuum (such as the ZPE) can be described by the action of Λ. It might be thought, then, that any change in vacuum energy density might be due to the direct action of this quantity. However, as Barrow and Magueijo point out *"If Λ > 0, then cosmology faces a very serious fine-tuning problem…There is no theoretical motivation for a value of Λ of currently observable magnitude …"* [37]

Furthermore, the problem of trying to incorporate Λ into ZPE theory by QED methods has proved very difficult. Zeldovich pointed out that the numerical value obtained for Λ from any proposed vacuum and particle theory can disagree with observation by up to 10^{46} as observation has suggested $\Lambda \sim 10^{-54}$ cm^{-2} or lower.[38] The same conclusion was reached via a different line of reasoning by Abbott.[39] More recently, Greene noted that

"…the cosmological constant can be interpreted as a kind of overall energy stored in the vacuum of space, and hence its value should be theoretically calculable and experimentally measurable. But, to date, such calculations and measurements lead to a colossal mismatch: Observations show that the cosmological constant is either zero (as Einstein ultimately suggested) or quite small; calculations [based on QED theory] indicate that quantum-mechanical fluctuations in the vacuum of empty space tend to generate a nonzero cosmological constant whose value is some 120 orders of magnitude larger than experiment allows!" [40]

This may indicate that the cause of the problem exists with QED and GR theory, while the SED approach may be more in keeping with observation. This line of thinking seems to be confirmed by Haisch and Rueda who concluded that "*the ZPF cannot be the manifestation of a cosmological constant, Λ, or vice versa…The ZPF is NOT a candidate source for a cosmological constant. The ZPF…can have nothing to do with Λ and is not, of itself, a source of gravitation… Gravitation is not caused by the mere presence of the ZPF, [but] rather by secondary motions of charged particles driven by the ZPF. In this view it is impossible for the ZPF to give rise to a cosmological constant"*.[41]

Discerning the Origin of the ZPE

Thus QED and GR approaches both result in difficulties since the ZPE is considered to be a manifestation of Λ. However, the SED approach may suggest a different origin for the ZPE independent of Λ. Puthoff noted there were two current explanations for the origin of the ZPE.[42] They were assessed as follows: "*The first explanation … is that the zero-point energy was fixed arbitrarily at the birth of the Universe, as part of its so-called boundary conditions.*"[43] A second school of thought proposes that *"the sum of all particle motions throughout the Universe generates the zero-point fields"* and that in turn *"the zero-point fields drive the motion of all particles of matter in the Universe … as a self-regenerating cosmological feedback cycle."*[43] On this second explanation the ZPE plus atomic and virtual particles require the existence of each other. Several papers on the topic have capably demonstrated that this mechanism can maintain the presence of the ZPE once it had formed, but avoid the question of its origin. Since Puthoff has shown that the ZPE is required to maintain atomic structures across the cosmos,[44] it becomes difficult to envisage how atomic structures emerged in the first place by the feedback mechanism. A closer look at conditions at the inception of the universe may be pertinent. An initial outline of a probable process was given in "Exploring the Vacuum",[14] but further work has been done since the publication of that paper. As a result, an updated summation may be appropriate here, even though a more fully developed account with the required mathematics is planned for a forthcoming paper.

When the cosmos underwent rapid expansion or inflation at its origin, the process fed energy into the vacuum. This energy manifested as the smallest particles the cosmos is capable of producing, namely Planck particle pairs (PPP). PPP have a unique property; their dimensions are also those of their own Compton wavelengths[45]. Each pair is positively and negatively charged so that the net result is that the vacuum is electrically neutral. Because quantum uncertainty only exists as a result of the ZPE according to SED physics, then there was no time limit initially for these particles to remain in existence as a physical reality. Furthermore, since the Planck length is the cutoff wavelength for the ZPE, these particles were thereby unaffected by the ZPE as it built up during the expansion process. As the cosmos continued to expand, the separation between particles increased, and the turbulence among the PPP resulted in spin. The separation between these charges gave rise to electric fields, while their spin created magnetic fields. This may be considered to be the origin of the primordial electromagnetic fields of the ZPE. By this means, the energy of the expansion was converted into the Zero Point Energy.

But we can go further than this. Five observational anomalies, three mentioned above, indicate the ZPE has been increasing with time. These are the increasing value of *h*, the decreasing value of *c*, the increasing value of *m*, the slowing rate of 'ticking' of atomic clocks, and the quantized redshift. These are all ZPE related hence PPP dependent. The reasons why the ZPE strength is increasing now needs to be summarized.

Why the ZPE Strength is Increasing

Gibson has pointed out that the expansion of the fabric of space will generate separation, spin and intense vorticity/turbulence between the PPP.[46] He demonstrated that this vorticity feeds energy into the system, which allows the production of more PPP. Therefore, additional PPP are spawned by this vorticity and turbulence. This means that, as long as turbulence continues, PPP numbers will increase. Thus, part of the reason for the increase in the strength of the ZPE may be found from the initial expansion of space and the effect of this on the Planck particle pairs.

However, the formation stage of vortex production is only the first of three phases. The other two phases are the persistence and decay phases which follow after initial vortex formation has occurred. Gibson [op. cit.] has pointed out that the PPP system is characteristically inelastic, while Bizon has established that such inelastic systems have stronger vortices and longer persistence times.[47] In these persistence and decay stages, the vorticity in the fabric of space would have continued, and hence more PPP would form via this ongoing process. This would result in an increase in the ZPE strength until the vorticity died away completely. Since the cosmos is a very large system with immense energies, the persistence and decay stages in the life of these vortices may be expected to be relatively long. As the strength of the ZPE builds up by this process, it would be maintained by the feedback mechanism mentioned earlier.[42-43]

One additional point is important. Under the conditions being considered here, PPP will have a tendency to re-combine due to electrostatic attraction. Once recombination occurs, a pulse of electromagnetic radiation is emitted with the same energy that the Planck particle pair had originally.[48] The resulting energy further augments the primordial electromagnetic ZPE fields. This recombination process will eventually eliminate the majority of the PPP, although the initial production of PPP from turbulence partly offsets that. The strength of the ZPE will thereby increase until these processes cease. Once that happens, the ZPE strength would be maintained by the feedback mechanism noted above.

The fact that the recombination of the PPP has occurred is evidenced by recent photographs from the Hubble space telescope and the discussion that has ensued. If the "*fabric of space*" is made up of Planck particle pairs as Greene indicated,[49] so that "*space assumes a granular structure*" as Pipkin and Ritter suggested,[50] then the ultimate result is that photographs of astronomical objects should be more "fuzzy" as distance increases. Such "fuzziness" is not in evidence despite several searches, and there has been some discussion about this in the scientific literature.[51 – 56] These observations suggest that the PPP which had originally formed as a result of the rapid expansion process have now nearly all recombined, leaving the ZPE as the only evidence of their original existence.

Thus the ZPE is an intrinsic feature of the physical vacuum due to the conversion of energy from the initial expansion of the cosmos. When the origin of the ZPE is considered in this fashion, its existence apart from the cosmological constant becomes a viable option. Furthermore, the anomalous behaviour of the physical constants is readily accounted for, behaviors which have no explanation using either the QED or relativistic approaches. The modeling here also has the advantage that the mathematical form of the behaviour of the ZPE, and the five anomalous quantities mentioned above, can be reproduced. In other words, the cosmological behaviour of the factor A that appears in equations (1), (5), (6), (8) and (32) can be derived from the physics involved.

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