The Vacuum-Lattice model – a new route to longitudinal gravito-electromagnetism

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A Vacuum Lattice (VL) model based on the lattice theory of elementary particles (Koshmieder, 2011) is used to generalise the Maxwell and Gravito-electromagnetic (GEM) field equations so they incorporate longitudinal electroscalar and gravity wave propagation. The model not only predicts the electroscalar energy flux observed by Monstein and Wesley (2002), it also provides simple mechanistic explanations of electron-positron annihilation, the Planck and Compton relationships, the vacuum permittivity and permeability, and the Cosmic Microwave Background. In addition a mechanistic explanation of "space-time" distortions in general relativity is presented. The paper ends with a discussion of several options for future research.

Keywords: Gravitation, Physical vacuum, Longitudinal electroscalar waves, Generalised Maxwell's equations; Gravito-electromagnetism (GEM)

1. Introduction

A recent publication has shown how the classical field equations of gravito-electromagnetism (GEM) can be derived, without approximation, from mass-energy conservation and how this leads to a “mass induction” phenomenon which provides a consistent explanation of Mach’s ideas about the cosmological origin of inertial mass (Hills, 2012). Despite this success, the GEM and Maxwell field equations fail to predict longitudinal waves, even though there is considerable experimental evidence for their existence (Tesla 1990; Monstein 2002; Podkletnov 2001). To try to overcome this shortcoming the author began to develop a new model of the vacuum called the Vacuum Lattice (VL) that builds on earlier ideas of Simhony (1990) and on the lattice theory of elementary particles presented by Koshmieder (2011). It was found that the VL model not only predicts the existence of longitudinal waves in electromagnetism and gravito-electromagnetism but also provides straightforward explanations of a wide range of other physical phenomena including electron-positron annihilation, the Planck and Compton relationships, and the magnitude of the vacuum permittivity and permeability. This paper reports on the progress to date and discusses several options for future research.

2. The Vacuum Lattice (VL) model

Because the Standard Model has, so far, failed to predict the masses of the elementary particles there have been numerous efforts to develop alternative theories (e.g. Skyrme, 1962; Martin 2005; El Naschie, 2008). One of the most successful is the “lattice model” that claims to predict the mass and spin of all the long-lived mesons, baryons and leptons, including the electron-, muon- and tau neutrinos (Koshmieder, 2011). This theory postulates that the elementary particles consist of lattices built from positive or negative “charge elements”, photons, neutrinos and antineutrinos. For example, the electron is modelled as a cubic lattice of N negative, near-massless, spin-zero, scalar particles (charge elements), C^-, each having a charge, $-q_l$, equal to 1/N of the electron charge, $-e_e$, held together by the weak force arising from a large number of neutrinos. Of course the positron has the same structure except that the charge elements are now the positively charged antiparticle (C^+) and anti-neutrinos replace neutrinos. The rest mass of the electron (or positron), m_e, is then the sum of the energy of all the neutrinos (or anti-neutrinos) together with the mass equivalent of the electrostatic energy of all the charge elements. An estimate of the number of charge elements in the electron or positron lattice can be made by assuming that the proton has the same charge element lattice as the positron. Scattering experiments show that the diameter of the proton is of the order of 10^{-15}m and the range of the weak force is known to be of the order of 10^{-18}m, which can therefore be taken as an order-of-magnitude estimate of the lattice spacing between the C^+ charge elements. If so, there must be about 10^3 charge elements along the length of the proton cubic lattice and 10^9 within its cubic volume. As a first approximation it can therefore be assumed that the electron and positron have the same lattice made of C^- and C^+ particles respectively and held together with (anti)-neutrinos. All the other hadrons and leptons are constructed around similar cubic lattices and contain various combinations of charge elements, neutrinos, antineutrinos and photons (Koshmieder, 2011).

Notwithstanding its success in describing elementary particles, this lattice model makes no attempt to develop a similar lattice theory of the vacuum, which we will now do by considering the mutual annihilation of an electron and positron into two gamma-ray photons. According to conventional physics the energy of the two gamma-ray photons comes from the rest mass of the two particles according to the Einstein mass-energy equivalence formula, $e = m_e c^2$ and the two charges, labelled $+e_e$ and $–e_e$, are assumed to disappear because their arithmetic sum is zero. But the vacuum lattice model proposed in this paper interprets this event in a radically different way by postulating that the conservation of electric charge implies that the charge elements, C^+ and C^-, are indestructible particles so it is only the neutrinos and antineutrinos in the electron and positron lattices that are converted into gamma photons. If so, the remaining charge elements must enter the vacuum and be incorporated into some form of "vacuum lattice" and the lowest energy configuration of this lattice would be a cubic lattice having alternating charges on neighbouring sites. In other words the postulate that charge elements are conserved implies that *the vacuum comprises an infinite lattice of the positive and negative charge elements, C^+ and C^-, arranged in a cubic lattice*. Support for the existence of this vacuum lattice comes from the simple observation that the vacuum permittivity is not zero, but has a finite value, suggesting it comprises charged particles that can be displaced from their equilibrium positions by external electric fields. Indeed the vacuum lattice model will be used to calculate the vacuum permittivity (and permeability) in section 9. The apparent 'disappearance' of the charge elements of the electron-positron pair on entering the vacuum lattice is also easily understood because it is somewhat analogous to the way in which a Na^+Cl^- ion pair apparently 'disappears' when it enters a salt lattice and arises because external electromagnetic forces can no longer interact with the ion pair *individually*, so it cannot be perceived. We do not, however, interpret the "disappearance" of the Na^+Cl^- ions as a mutual charge annihilation process! If the VL model is correct, the electron-positron charge is also not "annihilated", merely rearranged as charge elements in the vacuum lattice where they cannot be *individually* perceived by external fields.

This novel "annihilation" scenario can be quantified using the principles of gravito-electromagnetism and simple electrostatics. According to gravito-electromagnetism the mass loss equates to the loss of the gravitational potential energy, e, of an electron-positron pair which can be written, $2m_e\phi_{gb}$, where m_e is the mass of the electron or positron and ϕ_{gb} is the scalar gravitational potential arising from all the matter in the universe, which is,

$$\varphi_{gb} = \int_V dr^3 \frac{G\rho_{av}}{r} \tag{1}$$

where ρ_{av} is the average mass density of the universe. This integral cannot be evaluated directly but gravito-electromagnetism shows that, to be consistent with Newton's second law, it must have the value c^2 (Hills 2012). This means that the gravitational potential energy of an electron (or positron) is $e = m_ec^2$, and Einstein's well known equation has been derived without any reference to special relativity and results in the release of two gamma ray photons of combined energy, $2m_ec^2$. The electrostatic component of the electron and positron mass is also almost entirely lost in the annihilation event because the negative and positive charge elements are rearranged into an alternating pattern in the vacuum lattice. To show this we can calculate the electrostatic binding energy of a single charge element in the vacuum lattice, which is $Ae_e^2/N^2\delta$, where A is the Madelung constant, which takes account of the infinite lattice structure and δ is the mean lattice spacing between charge elements in the vacuum lattice. Unfortunately the precise lattice structure and the value of the lattice spacing are unknown, but for an order of magnitude estimate we can assume A has the value 1.747 for a face-centred cubic lattice and that the lattice spacing is the same as that in the electron and positron (ca. 10^{-18}m). If so, the electrostatic binding energy of N charge elements in the vacuum lattice is about 10^{-7} keV, which is negligible compared to m_ec^2, which is 511keV. We can therefore safely say that, regardless of the exact lattice structure or spacing, the mass equivalent of the electrostatic self-energy of the electron and positron is almost entirely lost when their charge elements enter the vacuum lattice. It does however mean that the electrostatic binding energy of the charge elements in the vacuum lattice is not exactly zero, but contributes a finite, but extremely small, rest mass of, $Ae_e^2/N^2\delta c^2$, to each vacuum charge element, C^+ and C^-.

Of course, if the vacuum lattice is not to collapse under Coulombic attractive forces there must also be a short-range repulsive force between neighbouring charge elements. This, we will assume, is the repulsive part of the weak force that also stops the charge elements and neutrinos collapsing in the electron (Koshmieder, 2011). If so, each charge element in the vacuum lattice sits in a "potential well" arising from long range electrostatic attractive forces and the much shorter range attractive and repulsive components of the weak force and these weak force interactions will also contribute to the small rest mass of the vacuum charge elements. Of course, the potential well also gives the vacuum lattice an inherent elasticity, which is a prerequisite for the propagation of longitudinal electromagnetic and gravitoelectric waves. This aspect will be discussed in greater detail later.

Because the charge elements in the vacuum lattice have such a small rest mass the vacuum mass density is negligibly small. This contrasts with an earlier lattice model of the vacuum proposed by Simhony in the 1980's. According to Simhony's model the vacuum comprised an infinite lattice of *real* electrons and positrons, so it was called the EPOLA (Electron POsitron LAttice) model (Simhony, 1990). However, in the opinion of this author, this EPOLA model is untenable because it ignores the possibility of electron-positron annihilation within the lattice and predicts an unreasonable mass density for the vacuum. Indeed, if the vacuum lattice comprises real electrons and positrons it has an enormous mass density, estimated as, m_e/δ^3, of about 10^{13}kg/m^3, or roughly 10^9 times more dense than iron! Simhony argued that although such a high density may be psychologically difficult for us to accept, it is not really a problem, because atomic nuclei, having diameters in the range 1.7fm (proton) to 15fm (Uranium), are, at least for the lighter elements, smaller than the mean electron-positron lattice spacing, estimated by Simhony to be 4.4fm, so they (and we) can pass through the vacuum lattice spaces without hindrance. This point is highly debateable, but there is a more serious problem with the EPOLA model because if the vacuum lattice comprises real electrons and positrons there can be no mass loss during the 'annihilation' process, so one needs to ask why two gamma ray photons of energy $2m_ec^2$ are liberated? As we have seen, this energy cannot be equated to the electrostatic binding energy of the EPOLA lattice because this would be too small by several orders of magnitude. The obvious conclusion is that the vacuum lattice does not contain real electrons and positrons but almost massless, spin-zero, parity +1, charge elements. The conservation of electric charge then implies that these charge elements can neither be created nor destroyed so that all elementary particles with a charge $\pm e_e$ must contain an excess of about 10^9 positive or negative charge elements, which implies that they all have a lattice structure!

3. Electromagnetic waves in the Vacuum Lattice

To develop the vacuum lattice model quantitatively we will, for simplicity, treat the lattice charge elements as classical particles that conform to the field equations of classical electromagnetism and gravito-electromagnetism (GEM). The charge elements therefore respond to external electric, magnetic and gravitational fields like any other charged particle with a non-zero rest mass. Vacuum lattice theory does not, therefore, provide a derivation of the Coulomb or Newton inverse square laws nor of the other terms in the Jefimenko field equations (Jefimenko, 2004). Indeed, such a derivation is unnecessary because all the field equations of classical electromagnetism and gravito-electromagnetism emerge naturally from the principles of charge and mass-energy conservation (Heras 2007a; Hills 2012). However the vacuum lattice does provide a mechanistic explanation of electromagnetic wave propagation because the charge elements can vibrate around their equilibrium lattice positions in the potential energy well created by long-range Coulombic attractive forces and short-range attractive and repulsive weak forces. We therefore postulate that transverse electromagnetic waves and longitudinal electroscalar waves are not just fields that are superposed on the vacuum but are directly related to the space and time derivatives of the collective displacements created by coherent vibrations of the vacuum lattice charge elements. In other words, "photons" have a direct correspondence with vacuum lattice "phonons". The derivation of the quantitative relationships between electromagnetic waves and vacuum lattice vibrations will be deferred to section 6. Here it is sufficient to note that this simple idea allows the energy of a photon to be calculated as the energy transferred per lattice charge element during the propagation of a lattice wave of wavelength, λ. Consider, first, longitudinal compression waves in the lattice, which we will later relate to longitudinal electromagnetic wave propagation and longitudinal photons. Let us assume that the wave is created by a very small oscillating source so that for all practical purposes the wave front is spherically symmetric. Then the number, n, of lattice particles in a sphere of radius, λ, is proportional to λ^3, and the compressional lattice wave will be associated with an alternating increase and decrease in the particle number, Δn, within the sphere, which is proportional to the surface area of the sphere, in other words, to λ^2. Because each lattice particle is associated with a lattice binding energy, the average energy transferred from one particle to another in a longitudinal lattice wave of wavelength, λ, which is proportional to the photon energy, e_{photon}, can be written,

$$e_{photon} \propto \frac{\Delta n}{n} \propto \frac{1}{\lambda} \qquad \text{so that} \qquad e_{photon} = \frac{B}{\lambda} \tag{2}$$

where B is a proportionality constant. A similar derivation applies to transverse wave propagation, except that, instead of a spherical wave front, we need to consider a small oscillating dipole source and a plane wave front with cubic geometry. The constant, B, can be determined by noting that, by definition, the Compton wavelength, λ_c, is the wavelength of a photon having the energy of an electron, so that,

$$e_{Compton\ photon} = m_e c^2 = \frac{B}{\lambda_c} \tag{3}$$

giving $B = \lambda_c m_e c^2$. Substituting for B in equation (2) gives,

$$e_{photon} = \frac{\lambda_c m_e c^2}{\lambda} = (\lambda_c m_e c)\nu = h\nu \tag{4}$$

which is the Planck relationship for the energy of a photon. This derivation shows that the velocity of light in the vacuum lattice must be, c, such that $c = \lambda\nu$ and that Planck's constant, h, has the value, $\lambda_c m_e c$, which means that the Compton wavelength, λ_c, is $h/m_e c$. In this way the velocity of light, Planck's constant, Planck's relationship and the Compton wavelength are all derived from the vacuum lattice model, which is certainly a strong argument in its favour.

If this description of the nature of electromagnetic waves is correct then it means that the random vibrations of the lattice charge elements about their equilibrium positions will also be associated with electromagnetic waves, but in this case it will be a thermalized black body spectrum of electromagnetic radiation. In the VL model this is the origin of the Cosmic Microwave Background (CMB), characterised by an equilibrium lattice temperature of 2.725K, defined by the mean, per-particle energy of the random vibrations. The low-level anisotropy of the CMB presumably arises from small local increases in the vacuum lattice temperature caused by its interaction with intense stellar and plasma radiation.

4. Gravity waves in the Vacuum Lattice

The derivation of Maxwell's equations from the principle of charge conservation and the similar derivation of the field equations of gravito-electromagnetism (GEM) from mass-energy conservation shows that the Maxwell and GEM field equations are entirely analogous (Hills, 2012). This means that the wave equations for electromagnetic and gravito-electromagnetic (gravity) waves are also entirely analogous, and this powerful analogy should be reflected in any mechanistic model of the vacuum. This is the case with the Vacuum Lattice model if we postulate that both electromagnetic and gravito-electromagnetic waves are collective, but distinct, modes of vibration in the lattice. This would not only explain the close analogy between these two phenomena, but also why the vacuum speed of gravity is the same as that of light. This may seem a trivial deduction but it is not easily explained with other mechanistic vacuum models (e.g. Urban, 2011) and is usually only justified with special relativity.

Before developing these ideas as a quantitative theory, it is worthwhile considering, qualitatively, how the collective lattice vibrations associated with electromagnetism and gravito-electromagnetism differ. Let us start with the lattice distortions associated with electromagnetic waves by considering an atomic nucleus that is stationary with respect to the vacuum lattice. The negative lattice charge elements are displaced towards the nucleus because of long-range Coulombic attraction whereas the positive charge elements are repelled. If the nucleus undergoes accelerated motion this characteristic Coulombic lattice distortion will propagate away at the speed of light and the propagating distortion results in an electromagnetic wave. Uniform motion of the nucleus will not create electromagnetic waves because the Coulombic distortion energy is conserved during elastic deformations. Expressed differently, the energy gained by distorting the lattice ahead of the uniformly moving nucleus is recovered when the lattice relaxes back to equilibrium behind it. There is therefore no net transfer of energy from the nucleus to the lattice in uniform motion and therefore no deceleration and no release of electromagnetic waves. This is the mechanistic origin of Newton's laws of motion. Incidentally, Simhony (1990) has argued that the lattice distortions ahead and behind the uniformly translating particle, such as a nucleus, are the origin of the "De Broglie wave" associated with the particle. However that leads to considerations of wave-particle duality and the mechanistic origins of quantum theory, which is outside the scope of this paper.

Other radiative modes in classical electromagnetism can be understood with the VL model. If the nucleus in the above example remains stationary but undergoes periodic internal charge rearrangements, then the usual multipole expansion predicts dipolar and quadrupolar electromagnetic waves propagating as distortions through the vacuum lattice. However, it is particularly important to note that if, hypothetically, the nucleus simply underwent periodic changes in its electric charge, then the VL model predicts that longitudinal electric waves would also radiate away from the nucleus! This would be the case even if the nucleus remained stationary with respect to the vacuum and if there were no higher-order multipolar distortions. In other words, the VL model goes beyond Maxwellian electrodynamics by predicting the existence of longitudinal electroscalar waves whenever the charge density is changed. However we will delay discussion of the quantitative theory behind longitudinal electroscalar wave propagation to section 6.

Consider now the gravitational lattice distortion taking, as an extreme example, a stationary, close-packed assembly of neutrons, such as a neutron star. There is no longer a Coulombic lattice distortion but there will be a weak long-range gravitational attraction of both the positive and negative vacuum charge elements towards the neutron assembly because they have a small rest mass. There will also be a short-range repulsion between the neutron assembly and the lattice particles that will tend to exclude them from the interior of the neutron assembly. Both effects cause a local increase in the number density of the lattice particles surrounding the neutron star and this increase is the characteristic ‘gravitational’ distortion of the lattice that is distinct from the electromagnetic distortion. As we shall see, the increased number density also reduces the local speed of light, which accounts, quantitatively, for the bending of light by a gravitational potential. If the neutron assembly undergoes accelerated motion then the distortion will propagate away at the speed of light and give rise to a gravitoelectric wave (Hills, 2012). Similarly, if the quadrupole moment of the neutron star changes, then quadrupolar gravity waves will be radiated out through the vacuum lattice. In addition, if, by some mechanism, the mass density of the neutron star were to change because it underwent symmetric radial expansion or collapse, then the VL model predicts that the resulting lattice distortion will also radiate away at the speed of light and give rise to a longitudinal gravito-electroscalar wave. This is predicted even when the neutron star is stationary and has no quadrupolar shape distortions. There will be a similar, but smaller, local increase in the vacuum charge element number density with less dense objects such as the Earth, except that, unlike the neutron star, the vacuum particles will be able to penetrate the body of the Earth. Just as "photons" are related to the phonons characterising the electromagnetic distortions of the vacuum lattice; so "gravitons" are related to the phonons characterising the gravitational distortion of the lattice.

The fact that the VL model predicts not just transverse, but also longitudinal electroscalar and gravito-electroscalar waves has been emphasised because, unfortunately, neither the unmodified Maxwell nor GEM field equations predict them! It is therefore necessary at this point to make a slight digression to analyse the reasons for this profound failure. The analysis will also provide a useful background for later quantitative developments.

5. The failure of the Maxwell and GEM field equations to describe longitudinal waves

Textbooks on electromagnetism point out that, in a vacuum, Maxwell's equations predict that electromagnetic waves are necessarily transverse polarised, which tacitly implies that longitudinally polarised electroscalar waves with finite velocity and energy flux do not exist. The same is true with the field equations of gravito-electromagnetism, which fail to describe longitudinal gravito-electroscalar waves. To see this we only need to substitute source-free electromagnetic waves of the form,

$$\mathbf{E}(\mathrm{x},\mathrm{t}) = \boldsymbol{\varepsilon}_\mathbf{1}\mathrm{E}_0\mathrm{e}^{\mathbf{ik.x}-\mathrm{i}\omega\mathrm{t}} \tag{5}$$

$$\mathbf{B}(\mathrm{x},\mathrm{t}) = \boldsymbol{\varepsilon}_\mathbf{2}\mathrm{B}\mathrm{e}^{\mathbf{ik.x}-\mathrm{i}\omega\mathrm{t}} \tag{6}$$

into the source-free Maxwell equations, div**E** = div**B** =0, to obtain $\boldsymbol{\varepsilon}_1.\mathbf{k} = \boldsymbol{\varepsilon}_2.\mathbf{k} = 0$, which shows that the waves are necessarily transverse polarised. But this argument assumes source-free plane waves, which leaves open the question as to whether special, spherically symmetric, sources can create longitudinal waves. Nevertheless we will now show that whatever the symmetry of the source and whatever theoretical trickery we try to impose on the Maxwell or GEM field equations, they conspire to prevent the transport of energy as a propagating longitudinal (gravito)-electroscalar field with a finite energy flux in the vacuum! We can begin our trickery by using Helmholtz's theorem which states that any vector, such as the (gravito)-electric field, **E**, may be written as the sum of an longitudinal (or irrotational) part, $\mathbf{E}_\mathbf{L}$, and a transverse (or solenoidal) part, $\mathbf{E}_\mathbf{T}$, such that,

$$\mathbf{E} = \mathbf{E}_\mathbf{L} + \mathbf{E}_\mathbf{T} \qquad \text{where } \boldsymbol{\nabla}\times\mathbf{E}_\mathbf{L} = 0 \text{ and } \boldsymbol{\nabla}.\mathbf{E}_\mathbf{T} = 0 \tag{7}$$

Applying this idea to both the **E** and **B** fields, the Maxwell or GEM equations can be rewritten as,

$$\nabla . \mathbf{E_L} = \alpha\rho \tag{8}$$

$$\nabla . \mathbf{B_L} = 0 \tag{9}$$

$$\nabla \times \mathbf{E_T} = -\gamma \frac{\partial \mathbf{B_T}}{\partial t} \tag{10}$$

$$\nabla \times \mathbf{B_T} = \beta \mathbf{J} + \left(\frac{\beta}{\alpha}\right) \partial(\mathbf{E_L} + \mathbf{E_T}) / \partial t \tag{11}$$

where α, β and γ are constants such that $\alpha = \beta\gamma c^2$. In electromagnetism $\alpha = 1/\varepsilon_0$; $\beta = \mu_0$ and $\gamma = 1$; whereas in gravito-electromagnetism $\alpha = -4\pi G$; $\beta = -4\pi G/c^2$ and $\gamma = 1$ (Heras, 2007a; Hills, 2012). In writing equations (8) to (11) we have made use of the fact that there can be no time-dependent longitudinal (gravito)-magnetic field because div$\mathbf{B_L}$ = curl$\mathbf{B_L}$ = 0 so that $\mathbf{B_L}$ is, at most, a constant. Taking the time derivative of equation (11) and using equation (10) with the vector identity

$$\nabla \times (\nabla \times \mathbf{E_T}) = -\nabla^2 \mathbf{E_T} \tag{12}$$

results in an uncoupling of the longitudinal and transverse fields:

$$\frac{\partial \mathbf{E_L}}{\partial t} = -\alpha \mathbf{J_L} \tag{13}$$

$$\frac{\partial \mathbf{E_T}}{\partial t} = \left(\frac{\alpha}{\beta}\right) \nabla \times \mathbf{B_T} - \alpha \mathbf{J_T} \tag{14}$$

The wave equations for the longitudinal and transverse components of the **E** field are obtained by taking the curl of equation (14) and the gradient of equation (8), which gives the *exact* equations,

$$\nabla^2 \mathbf{E}_\mathrm{T} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\mathbf{E}_\mathbf{T} = \gamma\beta \frac{\partial}{\partial t}\mathbf{J}_\mathbf{T} \tag{15}$$

$$\nabla^2 \mathbf{E}_\mathrm{L} = \alpha\nabla\rho \tag{16}$$

The transverse component of the (gravito-)electric field can be seen to propagate with the speed $(\alpha/\gamma\beta)^{1/2}$ which is c; but the longitudinal component has an infinite speed of propagation, giving instantaneous action at a distance, which contradicts the relativity of simultaneity in Special Relativity and therefore causality! This is the first indication that the Maxwell and GEM field equations are failing to properly describe longitudinal field propagation in the vacuum. José Heras made an attempt to fix this problem by pointing out that a propagating transverse electric field cancels the longitudinal field (Heras, 2007b). His argument proceeds by noting that $\mathbf{J}_\mathbf{T}$ in equation (15) is actually $(\mathbf{J}\text{-}\mathbf{J}_\mathrm{L})$ so that equation (15) together with equation (13) becomes,

$$\nabla^2 \mathbf{E}_\mathrm{T} - \frac{1}{c_i^2}\frac{\partial^2}{\partial t^2}\mathbf{E}_\mathrm{T} = \gamma\beta\left[\frac{\partial}{\partial t}\mathbf{J} + \alpha^{-1}\frac{\partial^2}{\partial t^2}\mathbf{E}_\mathrm{L}\right] \tag{17}$$

This shows that the longitudinal field acts as a source for the transverse field and the formal solution of equation (17) is,

$$\mathbf{E}_\mathrm{T} = -\iint d^3r' dt' G_R\left(\nabla'\rho + \frac{\gamma\beta}{\alpha}\frac{\partial \mathbf{J}}{\partial t'}\right) - \mathbf{E}_\mathrm{L} \tag{18}$$

where G_R is the retarded Green's function. Therefore the transverse solution always contains $-\mathbf{E}_L$, which cancels the longitudinal field. Unfortunately this does not completely fix the problem because, as we shall see, there are real experimental situations where the spherical symmetry of the source means that only longitudinal waves can be created, in which case there is no transverse wave to cancel the longitudinal wave! The longitudinal field equation (13) gives another peculiar prediction when we consider the propagation of waves in a medium that has a finite electrical conductivity, σ, such as dilute plasma, or even a copper wire. In such media, it is standard practice to supplement Maxwell's equations with Ohm's law, which states that, $\mathbf{J}_L = \sigma\mathbf{E}_L$. Equation (13) therefore becomes,

$$\frac{\partial \mathbf{E_L}}{\partial t} = -\alpha \mathbf{J_L} = -\alpha\sigma\mathbf{E_L} \tag{19}$$

which has the solution,

$$\mathbf{E_L}(\mathrm{t}) = \mathbf{E_L}(0)\mathrm{e}^{-\alpha\sigma\mathrm{t}} \tag{20}$$

This shows that, in a conductive medium, any propagating longitudinal electric wave will suffer exponential attenuation with increasing distance. But the equation breaks down when we consider the vacuum, which has zero conductivity, because equation (20) then predicts that only *static* longitudinal Coulombic electric fields are possible! Summarising, it appears that the Maxwell and GEM field equations predict that any longitudinal (gravito)-electroscalar field in the vacuum must either be static, or cancelled by transverse waves, or it must propagate with infinite velocity, and therefore contradict the relativity of simultaneity in

Special Relativity and therefore causality! These examples show that the field equations of Maxwellian electrodynamics and gravito-electromagnetism correctly describe transverse fields but *they do not permit longitudinal (gravito-)electroscalar waves in the vacuum to have a finite energy flux and speed, c*.

The reason for this peculiar breakdown of classical (gravito-)electromagnetism is readily appreciated when we realise that a longitudinal wave can only have a finite energy flux when the medium in which it is propagating has "elasticity". Indeed, it is well known that longitudinal compression waves with a finite speed and a finite energy flux exist in elastic solids. In plasma there are also longitudinal Langmuir waves which arise because the Coulomb force between charged particles acts as a restoring (or elastic) force. Longitudinal sound waves also transport energy through gases and liquids because increased pressure acts as a restoring force against compression. The reason Maxwell's equations do not permit a finite energy flux in the longitudinal mode in the vacuum is the assumption that the vacuum has zero elasticity, though this is rarely stated in textbooks! Of course, the vacuum lattice described earlier has elasticity so we now proceed to show how it leads to generalised Maxwell and GEM field equations with longitudinal wave propagation.

6. The vacuum lattice and generalised Maxwell and GEM field equations

Since the early days of electrodynamics there have been numerous attempts to describe longitudinal electroscalar wave propagation by generalising Maxwell's field equations. Recent contributions include Bettini's use of Clifford algebra to show how longitudinal and scalar fields emerge from a generalised potential field (Bettini, 2011). Van Vlaenderen has introduced an extra scalar field defined in terms of the Lorenz gauge (van Vlaenderen, 2008) and Podgainy has used the analogy with elasticity theory of solids to develop a generalised electromagnetism (Podgainy, 2010). However, as far as the author is aware, the vacuum lattice has never been used as the starting point for this endeavour, which is an omission that will now be addressed.

The electroscalar field

In addition to their extremely small rest mass the charged elements comprising the vacuum lattice also have an effective electromagnetic inertial mass. Electromagnetic inertia arises whenever an assembly of charges, of internal electrostatic energy, U_e, is accelerated (see, for example, Belcher, 2011). The accelerating charge (i.e. a changing current) creates a changing magnetic field that, in turn, induces an electric field that opposes the change in the current. This classical electromagnetic "back reaction" creates a force, $-(U_e/c^2)d\mathbf{v}/dt$, that resists the acceleration, where $\mathbf{v}$ is the velocity of the charge assembly. In other words, there is an effective electromagnetic inertial mass, U_e/c^2, which vanishes as soon as the acceleration stops, which is why it is a purely dynamical electromagnetic phenomenon that does not contribute to the rest mass. This idea can be applied both to the oscillating charge elements in the vacuum lattice as well as to a particle, such as a neutron or proton, accelerating through the vacuum lattice. In the later case, the particle would cause accelerated motion of the surrounding charge elements that would induce an electromagnetic back-reaction opposing the acceleration. In principle this would contribute to the inertial mass of the particle but it is expected to be negligible compared to the cosmological contribution to the inertia, which is $m_{int} = e_{int}/\phi_{gb} = e_{int}/c^2$ (Hills, 2012). Electromagnetic inertia does, however, mean that the vibrating charge elements in the vacuum lattice not only have a small rest mass but also a time-averaged electromagnetic inertial mass. Each vacuum charge element can therefore be associated with an effective mass, m_{eff}. Furthermore, the harmonic motion of the charge elements in their potential well can, like that of any other simple harmonic oscillator, be characterised by a force constant (or spring constant), k. Accordingly, the vacuum lattice can be approximated as a three dimensional array of point masses, m_{eff}, separated by a mean distance, δ, and connected by springs with a force constant, k. It was Robert Hooke in the 17th century who first analysed this type of lattice and showed that the longitudinal displacements, λ(r,t), of the particles (charge elements) obey a scalar wave equation in one dimension such that,

$$\frac{\partial^2\lambda}{\partial x^2} - \frac{1}{v^2}\frac{\partial^2\lambda}{\partial t^2} = 0 \qquad (21)$$

where the wave velocity, v, is,

$$v = \sqrt{\frac{k\delta^2}{m_{eff}}} \qquad (22)$$

But in the vacuum lattice we have already shown that, if Planck's relation is to hold, v must equal the speed of light, c, so equation (22) becomes,

$$c = \sqrt{\frac{k\delta^2}{m_{eff}}} \qquad \text{or} \qquad k = \frac{m_{eff}c^2}{\delta^2} \qquad (23)$$

Equation (23) will be used later in the derivation of the vacuum permittivity. The wave equation (21) can be generalised to three dimensions if we make the reasonable assumptions that the vacuum lattice is isotropic, homogeneous and has a Poisson ratio of zero, in which case,

$$\nabla^2\lambda - \frac{1}{c^2}\frac{\partial^2\lambda}{\partial t^2} = 0 \tag{24}$$

However, we have already seen that, in the vacuum lattice, electromagnetic and gravito-electromagnetic waves differ in the nature of the source and in the type of lattice distortions created by that source. We should therefore write,

$$\nabla^2\lambda_i - \frac{1}{c^2}\frac{\partial^2\lambda_i}{\partial t^2} = \alpha_i\rho_i \quad \text{where } i = e \text{ or } g \tag{25}$$

The subscript e or g refers to the characteristic lattice distortions created by electrostatic interactions (e) or gravitational interactions (g) while α_e is $1/\varepsilon_0$ and α_g is $-4\pi G$. Here $\rho_e(r,t)$ is the charge density of the source; while $\rho_g(r,t)$ is the source mass density. This can be further developed by noting that, as a mathematical identity, it is possible to represent a scalar wave equation such as (25) as a set of coupled linear differential equations by defining two new fields, which will be labelled $\mathbf{E}_{L,i}$ and W_i, as the space and time derivatives of the λ-field:

$$\mathbf{E}_{L,i} = \boldsymbol{\nabla}\lambda_i \quad \text{and} \quad W_i = -\frac{1}{c}\frac{\partial\lambda_i}{\partial t} \tag{26}$$

To conform to equation (25), $\mathbf{E}_{L.i}$ and W_i must obey the first order differential equation,

$$\nabla . \mathbf{E}_{L,i} + \frac{1}{c}\frac{\partial W_i}{\partial t} = \alpha_i \rho_i \tag{27}$$

Equation (27) correctly reduces to the longitudinal Maxwell equation (8) in the limit $W_i = 0$. In this way the λ_i-field assumes the role of a scalar potential determining the $\mathbf{E}_{L,i}$ and W_i fields; just as ϕ_i and $\mathbf{A}_i$ are the potentials determining the transverse electric, $\mathbf{E}_{T,i}$ and magnetic field, $\mathbf{B}_i$. From their definitions it can be seen that the two new fields also obey the linear differential field equations:

$$\nabla W_i + \frac{1}{c}\frac{\partial \mathbf{E}_{L,i}}{\partial t} = 0 \tag{28}$$

$$\nabla \times \mathbf{E}_{L,i} = 0 \tag{29}$$

This set of three linear field equations, (27) to (29), agrees with those independently derived by Bettini (2011) and by Podgainy (2010) but the vacuum lattice model has the unique advantage that it provides a straightforward derivation from a physical model and therefore provides mechanistic meaning to the fields: $\mathbf{E}_{L,e}(r,t)$ is the longitudinal electric field created by the characteristic electromagnetic type of longitudinal displacement, $\lambda_e(r,t)$, of the charge elements in the vacuum lattice; while $W_e(r,t)$, as we shall show, is related to the local excess charge density created by the longitudinal lattice displacements, $\lambda_e(r,t)$. Likewise, $\mathbf{E}_{L,g}(r,t)$ is the longitudinal gravitoelectric field created by the characteristic gravitational-type of longitudinal displacement, $\lambda_g(r,t)$, of the charge elements in the vacuum lattice; while $W_g(r,t)$, is related to the local excess number density created by the longitudinal lattice displacements, $\lambda_g(r,t)$. Taking the space and time derivatives of equation (25) and using the field definitions gives the wave equations for $\mathbf{E}_{L,i}$ and W_i:

$$\nabla^2 \mathbf{E}_{L,i} - \frac{1}{c^2}\frac{\partial^2 \mathbf{E}_{L,i}}{\partial t^2} = \alpha_i \boldsymbol{\nabla} \rho_i - \alpha_i \sigma_i \mathbf{E}_{L,i} \tag{30}$$

$$\nabla^2 W_i - \frac{1}{c^2}\frac{\partial^2 W_i}{\partial t^2} = -\frac{\alpha_i}{c}\frac{\partial \rho_i}{\partial t} \tag{31}$$

The electromagnetic waves associated with longitudinal lattice vibrations are now seen to be $E_{L,e}$-W_e waves; while longitudinal gravity waves are simply $E_{L,g}$-W_g waves. In equation (30) we have followed equation (19) and added a dissipation term proportional to the medium conductivity, σ_i. This is meaningful for electromagnetism but we will assume σ_g is zero because matter, as far as we know, does not significantly attenuate gravity waves. As anticipated by our earlier qualitative discussions of lattice distortions, equations (30) and (31) identify the source of the longitudinal (gravito)-electroscalar waves as the space and time derivatives of the mass or charge density. In other words, unlike transverse electromagnetic E_T-B waves, electroscalar E_L-W waves require a source with a varying charge density. As we shall see, such a source could be the alternating net electric charge on a metal sphere connected to an AC generator. In the case of the analogous gravito-electroscalar waves the source mass density must vary, which would be the case with spherically symmetric explosions, collapses or oscillations. The conclusion must be that the generation of (gravito)-electroscalar waves not only requires a vacuum with finite elasticity but also a source with a varying charge (or mass) density.

Expressions for the energy density and flux of the longitudinal fields can be obtained in the usual way. Multiplying equation (27) by W_i and (28) by $\mathbf{E}_{L,i}$, adding the two equations and integrating over volume gives the energy conservation equation,

$$\frac{\partial}{\partial t}\int e_{EWi} dV + \oint \mathbf{S}_{EWi} \mathbf{d}\sigma = 0 \qquad (32)$$

where the field energy density, e_{EW} is

$$e_{EW} = (\mathbf{E}_{L,i}^2 + {W_i}^2)/2 \qquad (33)$$

and the energy flux vector, $\mathbf{S}_{EWi}$, is

$$\mathbf{S}_{EWi} = c\mathbf{E}_{L,i} W_i \qquad (34)$$

Note that a longitudinal energy flux requires both the $\mathbf{E}_{L,i}$ and W_i fields. In other words it is the (gravito)-electroscalar $E_L W$-field that is propagated and which has a non-zero energy flux, and not the separate $\mathbf{E}_{L,i}$ or W_i fields. Because the $E_L W$-electroscalar field is a consequence of a vibrational wave in the vacuum lattice, we could, if we wish, use the well-known method of second quantisation to define "longitudinal or electroscalar photons" which are associated with the longitudinal lattice phonons characterising the electromagnetic lattice distortion, λ_e. Similarly "longitudinal or scalar gravitons" could be defined in an analogous way to the lattice phonons characterising the longitudinal gravitational lattice distortion, λ_g.

The transverse fields in the vacuum lattice

Just as the electroscalar fields, $\mathbf{E}_{L,i}$ and W_i, can be defined as the space and time derivatives of the scalar potential, λ_i, so the transverse fields $\mathbf{E}_{T,i}$ and $\mathbf{B}_i$ are defined in the conventional way as space and time derivatives of the scalar and vector potentials, ϕ and $\mathbf{A}$:

$$\mathbf{E}_{T,i} = -\boldsymbol{\nabla}\phi_i - \gamma\frac{\partial \mathbf{A}_{T,i}}{\partial t} \tag{35}$$

$$\mathbf{B}_i = \boldsymbol{\nabla}\times\mathbf{A}_{T,i} \tag{36}$$

Here the potentials obey the Maxwell equation (Jackson, 1998)

$$\nabla^2\phi_i + \gamma\frac{\partial}{\partial t}\left(\boldsymbol{\nabla}.\mathbf{A}_{T,i}\right) = -\alpha_i\rho_i \tag{37}$$

Note that the (gravito)-magnetic field, $\mathbf{B}_i$ = curl$\mathbf{A}_{T,i}$, which has no longitudinal component, is only non-zero for a transverse vector potential, $\mathbf{A}_T$, so that div$\mathbf{A}_{T,i}$ is zero and the Coulomb gauge applies. This means that equation (37) reduces to the Poisson equation,

$$\nabla^2\phi_i = -\alpha_i\rho_i \tag{38}$$

showing that the scalar potential, ϕ_i, is just the instantaneous Coulomb (or gravitational) potential and plays no part in the propagation of (gravito)-electroscalar waves. In the vacuum lattice model the transverse vector potential, $\mathbf{A}_{T.i}$, is linearly related to the transverse lattice particle velocity, $\mathbf{v}_T(t)$, and obeys the familiar wave equation,

$$\nabla^2\mathbf{A}_{T,i} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\mathbf{A}_{T,i} = -\beta\mathbf{J}_{T,i} \tag{39}$$

where $\mathbf{J}_{T,i}$ is $\rho_i \mathbf{v_T}$ and ρ_i is the source charge density or mass density. Equation (39), together with the definitions (35) and (36) give the well-known wave equations,

$$\nabla^2 \mathbf{E}_{T,i} - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\mathbf{E}_{T,i} = \beta \frac{\partial \mathbf{J}_{T,i}}{\partial t} \quad (40)$$

$$\nabla^2 \mathbf{B}_i - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\mathbf{B}_i = -\beta \nabla \times \mathbf{J}_{T,i} \quad (41)$$

The longitudinal and transverse fields can therefore be rigorously uncoupled in the vacuum lattice provided we use the field equations (27) to (29) for the longitudinal fields and equations (7), (10) and (14) for the transverse fields. Unfortunately, deriving the (gravito)-electroscalar $\mathbf{E}_{L,i}$ and W_i fields from the vacuum lattice model in this way does not prove they really exist. That can only be decided by experiment, to which we now turn.

7. Experimental observation of longitudinal waves

7.1 Electroscalar waves

Over a hundred years ago, Tesla researched the existence of electroscalar waves and even took out patents for the wireless transmission of longitudinal electric energy around the world (Tesla, 1900). Unfortunately he was unaware of the existence of the conducting ionosphere, which via the term $-\alpha_e \sigma_e \mathbf{E}_{L,e}$ in equation (30) would exponentially attenuate any longitudinal electroscalar wave propagating over large distances. Nevertheless Tesla's ideas have had a profound scientific impact and are still being researched. As recently as 2002, Monstein and Wesley explored longitudinal electric wave propagation over more modest distances of several hundred meters (Monstein, 2002). They used a 6cm diameter hollow metal sphere as a transmitter and a similar one as a receiver because the spherical symmetry precludes any transverse wave transmission. The transmitting sphere was fed with AC current at a frequency of 433.59MHz and transmitted a wave that was picked up by the receiving sphere, and could be used as a source of energy, for example, to light a bulb. For this experiment, the source charge density had the form,

$$\rho(\mathrm{r},\mathrm{t}) = \mathrm{Q}\delta(\mathrm{r}-\mathrm{R})\sin\omega\mathrm{t} \tag{42}$$

where R is the sphere radius and Q is the net charge. The solution to the λ-wave equation (31) with the source equation (42) in the absence of the conducting term and for R = 0 is,

$$\lambda(\mathrm{r},\mathrm{t}) = \frac{\mathrm{Q}\sin(\mathbf{k}.\mathbf{r}-\omega\mathrm{t})}{\mathrm{r}} \tag{43}$$

so the spherically symmetric propagating electroscalar field is given as,

$$\mathbf{E_L}(\mathrm{r},\mathrm{t}) = \nabla\lambda = \frac{\mathrm{Q}\mathbf{k}\cos(\mathbf{k}.\mathbf{r}-\omega\mathrm{t})}{\mathrm{r}} - \frac{\mathrm{Q}\sin(\mathbf{k}.\mathbf{r}-\omega\mathrm{t})}{\mathrm{r}^2} \tag{44}$$

$$\mathrm{W}(\mathrm{r},\mathrm{t}) = -\frac{1}{\mathrm{c}}\frac{\partial\lambda}{\partial\mathrm{t}} = \frac{\omega\mathrm{Q}\cos(\mathbf{k}.\mathbf{r}-\omega\mathrm{t})}{\mathrm{cr}} \tag{45}$$

and the energy flux, $\mathbf{S_{EW}}$, is, according to equation (34) readily calculated as $\mathrm{c}\mathbf{E_L}\mathrm{W}$. Monstein and Wesley derived similar equations but, controversially, they used the scalar potential, ϕ, and not λ, in their derivation. To investigate the polarisation of the wave, they used an array of nine half-wavelength (34.6cm) metal rods fixed parallel to each other in a 3-by-3 square pattern. This array was placed between the transmitter and receiver. Figure 1 shows the measured dependence of the power transmitted through the polarising array on the angle, θ, between the rods and the line connecting the two spheres. It can be seen that when θ is zero, no power is transmitted, confirming the longitudinal polarisation of the electric field. The line is the theoretical curve derived from the energy flux $\mathbf{S_{EW}}$. Both the longitudinal polarisation and the non-zero energy flux were demonstrated in another way by introducing a radially oriented half-wave dipole with a light bulb in the centre of the dipole. The bulb only lit when the dipole was oriented radially but not when oriented tangentially to the transmission sphere. In a second experiment, the transmission frequency was reduced to 1 Hz, and the received power was plotted as a function of distance

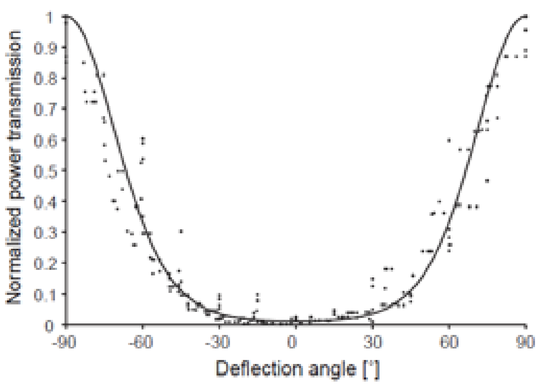

Figure 1. The dependence of transmitted power on the angle θ between the metal rods and the line between the two metal spheres, confirming longitudinal polarisation. (Taken from Monstein and Wesley, 2002).

between the two spheres (figure 2). This not only confirmed the transmission of longitudinal electric waves over several hundred meters, but also the severe attenuation of the signal with distance that renders Tesla's ideas of wireless energy transmission over long distances, impractical. The attenuation arises both from the expected $1/r^2$ dependence of the energy flux predicted by equation (44), but also because of an exponential decrease with distance described by equation (30). Over this distance the exponential decay arises because the Earth's surface has a finite electrical conductivity, so that it gives Ohmic resistance and dissipation. The maxima and minima observed in the data show a small interference effect arising because the Earth's surface, having a weak electrical potential, creates a partial image of the transmitter. The solid line is the predicted interference pattern, which agrees only in a semi-quantitative way because the theory does not take account of the precise conditions of the Earth's surface charge.

Monstein and Wesley's experiments therefore confirm the essential features of transmitted electroscalar waves and strongly suggest that the vacuum acts as an elastic medium that can be modelled with the vacuum lattice. Unfortunately, Monstein and Wesley made no attempt to measure the velocity of the longitudinal wave, which should be c if the vacuum lattice model is correct. In addition, if equations (30) and (31) are correct, then any explosion involving a non-zero radial pulse in the charge density, $\rho(t)$, should create a pulse of electroscalar waves. In astrophysics, this would be the case with Nova and Supernova explosions, but it is unlikely that electroscalar waves could propagate over interstellar or intergalactic distances without severe exponential attenuation through interaction with the dilute conducting plasma filling space.

Quite obviously, there is sufficient experimental evidence and theoretical justification to warrant more intensive research into the properties of electroscalar waves. It would be particularly interesting to try to measure the wave velocity and to establish standing wave interference patterns between electroscalar waves. If such experiments confirm Monstein and Wesley's results it would

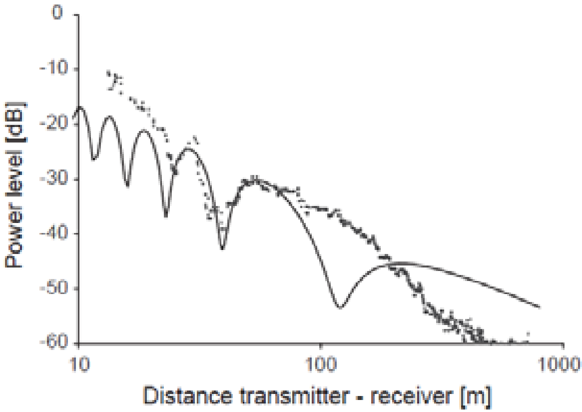

Figure 2. The dependence of transmitted power on distance between the two metal spheres, taken from Monstein and Wesley (2002).

appear that electroscalar waves could be used over short distances for the wireless transmission of electrical energy, as Tesla had hoped. However, before that application could be seriously considered, the effect of intense electroscalar waves on biological tissue (including humans) would also need to be researched to avoid unintended electrocutions!

7.2 Longitudinal gravitoelectric waves

The theoretical analysis in section 6 applies to both electric and gravitoelectric fields, so the vacuum lattice model also predicts the existence of gravito-electroscalar waves having a finite energy flux, propagating at light speed. However only experiment can decide whether this prediction is valid, and unfortunately, to date, there have been few attempts to detect them and there are no clear-cut observations of longitudinal gravity waves. The only reports of a propagating gravity pulse with longitudinal polarisation and non-zero energy flux are the two highly controversial publications by Podkletnov (1997) and Podkletnov and Modanese (2001) who claim to have created longitudinal gravity pulses in the laboratory. This polarisation was shown by observing that the effect of the pulses on a microphone decreased as the angle between the line normal to the microphones surface and the direction of propagation increases. Unfortunately, other research groups have, so far, failed to reproduce the effect so a great deal of scepticism surrounds these experiments.

Before leaving the subject of gravito-electroscalar waves, it is interesting to note that researchers in general relativity have also speculated about the existence of scalar gravity waves. These "Scalar-Tensor" theories are a variation on Einstein's original tensor theory (Wagoner, 1970), the best known being that of Brans-Dicke (2005). These theories also predict scalar gravity waves radiating from spherically symmetric sources (Haroda et al., 1997).

8. Vacuum permittivity and permeability

Predicting the magnitude of the vacuum permittivity and permeability is another useful test of the VL model that, surprisingly, has never been attempted. The vacuum permittivity can be derived by noting that an external electric field, E, polarises the vacuum lattice because it exerts a force on the lattice charge elements shifting them off their equilibrium positions in opposite directions. The Lorentz force on a single negative charge element in the lattice is q_l E, which will be opposed by a restoring force, kΔ, where k is the lattice spring constant discussed in section 6 and Δ is the displacement from the equilibrium position. At equilibrium in the electric field these forces are equal, so that $q_l E = k\Delta$, or $\Delta = q_l E/k$. But the induced dipole moment, d, in a displaced pair of charge elements, is $2q_l\Delta/N$, so substituting for Δ gives,

$$d = \frac{2{q_l}^2 E}{k} \tag{46}$$

The vacuum polarisation, P, for a lattice of N charge elements, of volume V ($=N\delta^3$) is Nd, and the permittivity, ε_0, is defined as $P = \varepsilon_0 EV$, so we deduce that,

$$\varepsilon_0 = \frac{2N{q_l}^2}{kV} \tag{47}$$

Substituting for k from equation (23) gives,

$$\varepsilon_0 = \frac{2{q_l}^2}{m_{eff}c^2\delta} \tag{48}$$

But m_{eff} can always be written as some fraction of the electron mass, m_e, and the lattice spacing will also be some fraction of the Compton wavelength, λ_c. Similarly, q_l, will be some fraction of the electron charge, so equation (48) can be rewritten,

$$\varepsilon_0 = D.\frac{{e_e}^2}{m_e c^2 \lambda_c} = D.\frac{{e_e}^2}{c\hbar} \tag{49}$$

where we have substituted the expression, $h/m_e c$, for the Compton wavelength derived earlier and introduced "D" as a dimensionless proportionality constant. This shows that the vacuum permittivity is determined by the three fundamental physical constants, e_e, c and ħ and is independent of the effective lattice particle mass, m_{eff}, the lattice spacing, δ, or the charge on the lattice particle, q_l. Substituting the experimental vacuum permittivity into equation (49) gives a value for D of 10.9. It is gratifying to note that equation (49), also with a dimensionless proportionality constant, has been obtained in a very different way by calculating the polarisation of transient fermion-antifermion pairs by an external electric field using a plasma model of the vacuum (Urban, 2011).

The vacuum permeability, μ_0, also has a finite value that can be derived by noting that the linearly polarised transverse vibrations of each lattice charge element can be considered to be the sum of two circular motions in opposite directions. In the absence of an external magnetic field the sum of the magnetic moments created by these two opposite circulating electric currents is, of course, zero. But in the presence of a magnetic field the current with the magnetic moment parallel to the field has a slightly lower energy than the one opposing the field. As a result the currents change by an amount, ΔI, to lower the energy and the charge element acquires an induced magnetisation, ΔM. This can be quantified by noting that the induced circulating current in each vacuum charge element is the charge times its velocity, which is $q_l \Delta\omega\delta$, so we can write,

$$\Delta I = q_l(\Delta\omega)\delta = q_l\left(\frac{g q_l B}{2m_{eff}}\right)\delta = \frac{g q_l^2 B\delta}{2m_{eff}} \qquad (50)$$

where $\Delta\omega$ is the Larmor precession frequency of the magnetic dipole created by the induced current, ΔI, and g is the gyromagnetic ratio for the charge element. It follows that,

$$\Delta M \propto \frac{q_l^2 B\delta}{m_{eff}} \tag{51}$$

But the vacuum permeability, μ_0, is defined as the ratio $B/(\Delta M)$ where ΔM is the magnetisation per unit area. Therefore,

$$\mu_0 = \frac{B(\pi\delta^2)}{\Delta M} \tag{52}$$

Substituting for ΔM from equation (51), and noting, once again, the proportionality between m_{eff} and m_e; δ and λ_c and q_l with e_e, we obtain

$$\mu_0 = F\frac{\hbar}{c{e_e}^2} \tag{53}$$

where F is a dimensionless proportionality constant. Like the vacuum permittivity, we find that the vacuum permeability depends only on the fundamental constants $\hbar$, c and e_e. Taking the product of equations (49) and (53) gives,

$$\mu_0\varepsilon_0 = \frac{b}{c^2} \tag{54}$$

and we have succeeded in deriving, to within a proportionality constant, b (=DF), the Maxwellian relationship between the vacuum speed of light and the vacuum permittivity and permeability using the vacuum lattice model. The model also correctly predicts that there can be no vacuum Faraday effect because the Larmor precession of the induced magnetic moments for positive and negative charge elements will be in opposite directions.

Incidentally, because the diameter of an atom, such as hydrogen, is many orders of magnitude greater than any reasonable estimate of the vacuum lattice spacing it means that quantum mechanical calculations of atomic or molecular structure can safely ignore the lattice structure and treat the vacuum as a continuous medium with a permittivity, ε_0, and permeability, μ_0. For the same reason the field equations of electromagnetism can be derived from the principle of charge conservation in terms of ε_0, and μ_0 without any reference to the vacuum lattice (Heras, 2007a). Although the field equations of gravito-electromagnetism are analogous to those of electromagnetism and can be derived from the principle of mass-energy conservation (Hills, 2012), the fact that the charge elements have the same rest mass means that it is not possible to define gravitational equivalents of the vacuum permittivity and permeability. Instead the role of gravitational permittivity and permeability is taken over by the gravitational constant, G.

9. The vacuum lattice and the bending of light by external potentials

We are now in a position to quantify the earlier qualitative discussion of the way that a large mass, M, such as a neutron star, causes a local increase in the number density of the vacuum lattice particles surrounding it. This increase in number density at a radial distance, r, is, of course, associated with a decrease in the local lattice spacing, $\delta(r)$, and a decrease in the local speed of light, $c(r)$, causing the photon transit time, $T(r)$, which is $\delta(r)/c(r)$, to increase.

In gravito-electromagnetism these changes are described by an exponential space-time metric, such that the contraction in lattice spacing is given as $\delta(r)/\delta = \gamma_{gem}^{-1}$, and the photon transit time is dilated such that $T(r)/T = \gamma_{gem}$ where γ_{gem} is $\exp(GM/rc^2)$ (Hills, 2012). This exponential metric is, of course, the same as that proposed by Yilmaz (1976) in his modifications of general relativity. It implies that the vacuum speed of light, c(r), in a static gravitational potential, is exponentially decreased such that $c(r) = \delta(r)/T(r) = c\gamma_{gem}^{-2}$. Substituting c(r) into equations (49) and (53) gives,

$$\frac{\mu_0(r)}{\mu_0} = \frac{\epsilon_0(r)}{\epsilon_0} = \frac{c}{c(r)} = \frac{n(r)}{n} = \gamma_{gem}^2 \qquad (55)$$

where n(r) is the vacuum refractive index in a gravitational potential. It is important to note that the ratio, ε_0/μ_0, is invariant to changes in gravitational potential, and this must be the case otherwise the ratio of electric and magnetic energies would vary in a gravitational field and energy conservation would be violated. Note also how equation (55) ensures that the fine structure constant, α, which is $e_e^2/4\pi\epsilon_0\hbar c$, is also invariant to gravitationally induced changes in the vacuum properties. This is necessary if the ratio of the strength of the interaction between electrons and photons is invariant to changes of gravitational potential. The dependence of the vacuum refractive index on gravitational potential predicted by equation (55) is the basis of the alternative formulation of general relativity developed by Puthoff (2002) and which correctly reproduces the PPN tests of general relativity, including the bending of light around the Sun and the Shapiro time delay. The vacuum lattice model now shows that the underlying mechanistic reason for this success lies in the changes to the space-time metric defined by the lattice spacing, δ, and the photon transit time, δ/c. The changes in these lattice space-time parameters caused by external gravitational fields give the mechanistic explanation of "space-time distortions" in general relativity.

The fact that electric and magnetic fields also distort the vacuum lattice implies that light will be bent by intense electric and magnetic fields. This is observed, for example, in the autofocusing of intense laser beams in the vacuum. By similar reasoning the vacuum lattice model predicts that gravitational waves will be bent by static gravitational potentials, though our current failure to detect gravity waves means that this prediction will be difficult to test!

10. Discussion

Despite its radical nature, the vacuum lattice model succeeds in explaining a diverse range of physical phenomena from the annihilation of electron-positron pairs to the observation of longitudinal electroscalar waves with a finite energy flux (Monstein and Wesley, 2002). The case for the VL model is further strengthened by the way it provides a straightforward mechanistic explanation of the nature of electromagnetic and gravito-electromagnetic waves and gives simple derivations of Planck's relation, Planck's constant, the Compton wavelength, the vacuum permittivity, vacuum permeability and vacuum refractive index as well as the equality of the vacuum speed of gravity and light, in the absence of external potentials. Together with the generalised gravito-electromagnetic field equations the vacuum lattice model also provides a quantitative description of how gravitational potentials and intense electric and magnetic fields can bend light. It even predicts the existence of the Cosmic Microwave Background as thermalized black body radiation emitted by the vibrating charge elements comprising the vacuum lattice.

It is interesting to note that the VL model shows how observable physical quantities, such as the vacuum permittivity and permeability can all be expressed in terms of the fundamental constants, c, h and e_e, without the need to quantify the unobservable model parameters such as the lattice spacing, δ, the force constant, k, and the effective electromagnetic inertia, m_{eff}. This means that these unobservable parameters are, to some extent, arbitrary. For example, the Vacuum Lattice model would give the same observable results if we assumed that the lattice charge elements were massless electrons and positrons themselves rather than their constituent charge elements. However, it is not only the desire to integrate the model with the lattice theory of elementary particles (Koshmieder, 2011) that suggests that the vacuum charges are the charge elements within electrons and positrons. The fact that "neutrino spin-light" is not observed when neutrinos propagate through the vacuum argues against the idea that the charge elements could be actual massless electrons and positrons with spin-1/2. Neutrino spin light is predicted whenever a neutrino interacts via the weak force with a dense medium containing electrons and positrons (Lobanov, 2003, 2004).

It is also interesting to consider how the VL model interprets electron-positron pair creation when a gamma ray photon of energy, $2m_ec^2$, impinges on an atomic nucleus. On first consideration it appears that we have an insuperable difficulty in overcoming the entropic barrier of separating about 10^9 positive and negative charge elements out of the vacuum and collecting them, together with an equal number of neutrinos and antineutrinos, in the form of an electron and positron! However this may not be such a problem if the high-energy gamma ray effectively "melts" the vacuum lattice so that the charge elements easily separate in the powerful electric field of the atomic nucleus. At the same time the presence of the intense electric field would trigger the creation of the neutrino-antineutrino pairs (Lobanov, 2006). This suggests that the atomic nucleus is necessary not just for momentum conservation by absorbing the momentum of the gamma ray photon, but also because it provides an extremely powerful local electric field for separating the vacuum charge elements and triggering neutrino-antineutrino pair production.

It is gratifying that the VL model integrates smoothly with the lattice theory of elementary particles. However, there is still the need to develop a quantum-mechanical version of the lattice models of both elementary particles and the vacuum. This should include a treatment of the zero point energy of the lattices and a vacuum lattice treatment of wave-particle duality and of the mechanistic origin of quantum theory alluded to in the main text.

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