On The Electromagnetic Basis for Gravity

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The relationships between two alternative theories of gravity, the "physicalist", Electromagnetics based, "Polarisable Vaccuum" theory of Puthoff and Dicke, and Yilmaz's "phenomenological" variation of the General Theory of Relativity, are explored by virtue of a simple physical model based in the application of Newtonian mechanics to propagative systems. A particular virtue of the physical model is that, by introducing distributed source terms, it anticipates nonlocal relationships between observables within the framework of local realism.

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1 Introduction

Early in the study of Electrodynamics it was shown (see for example [1]) that the increase in the effective mass of an electron when accelerated to relativistic velocities can be explained in terms of the increased energy of its Electromagnetic fields. This suggests that it might be better to think of the mass/energy of an apparent "point particle" as being distributed throughout its fields rather than being concentrated at the specific place where we tend to "find" a particle. On this view, the charged particle "sources" of "attached" [1] EM fields as usually written into Maxwell's Laws, are not sources, and nor are the fields attached to any actually existent atomist particles.

This possibility is highly relevant to many of the foundational issues in Physics because, if it were so, the usual assumption that interactions between sub-atomic particles are necessarily retarded relative to their observed locations would be falsified, as discussed here in section 4. The variety of modern experiments [2, 3, 4, 5] and observations on gravity [6] which together imply the nonlocal character of relationships between observables, would not then lead to the conclusion of intrinsically nonlocal, or even superluminal, interactions between ontological elements. In this context, Redhead [7] has shown that epistemological nonlocality (i.e. at the level of relationships between observables) does not strictly imply ontological nonlocality (i.e. interactions at a distance between physical elements that are not co-located). As particular instances of this, Wang et al [5] and Olkohvsky, Recami and Salesi [4] have each shown the existence of nonlocal relationships between observables within the usual, locally realistic wave theory. Given that waves, of any kind, are inherently distributed systems involving correlations at a distance as opposed to action at a distance, this is not as surprising as it might seem at first sight.

It has also been shown [8] that local realist wave soliton models of subatomic particles automatically conform to the usual relativistic mechanics. This result follows from two assumptions, namely conservation of linear momentum and a dynamical constraint such that the momenta carried by fields propagate at the characteristic velocity in all contexts. Therefore, the result applies to a wider class of models than the usual Electromagnetics formalism, which is relevant because Electromagnetics only contemplates interactions between fields and particles, whereas wave solitons require direct interactions between propagating fields. Nonlinear extensions to the usual formalism (which would provide direct field-field interactions and soliton solutions), have been studied (eg [9, 10, 11, 12]), and even more generally, it has been found [13] that there are systems of nonlinear equations whose solutions superpose linearly, whilst Cui [14] has shown that, if we are given only conservation of the norm of the 4-momentum for particles, then particle-particle interactions conform to the usual formalism as encoded in Maxwell's Laws and the Lorentz force Law. In other words, the basic proposition that energy-momentum is propagative generates both Special Relativity and Electromagnetics, but does so without precluding the existence of non-linear post-Maxwellian field equations that have soliton, or more precisely solitron[1], solutions. The purpose of the present article is to incorporate general relativity by taking the same basic proposition over from the idealisation of a perfect medium, which led to Special Relativity, to a more realistic scenario in which we admit that any real physical medium would

[1]Meaning any persistent solution to a non-linear field model. The term was coined by Chernitskii [15] to avoid confusion with the usually quite specific mathematical connotations of the word soliton.

have to be finite. Since the only property of the medium that was relevant for the Lorentz Group was the characteristic velocity, we aim to account for gravity by identifying a (hopefully simple) relationship connecting variations in the characteristic velocity with the (energy[2]) density of disturbances impressed upon the medium. This notion, that gravitational phenomena can be mimicked by suitably varying the characteristic velocity in the vicinity of massive objects, has been extensively studied [16, 17, 18, 19] etc, and we shall refer to such approaches as Refractive Medium Interpretations of gravity (RMIs). Amongst a large body of literature in the area, three facts emerge which should be brought to the attention of readers.

First, it has been shown (by virtue of the ”optical action” concept [17]) that Newtonian methods (i.e. force and energy methods) are available in curved spaces without approximation. The proof relies on the ability to define a scalar refractive index, which is equivalent to the availability of a coordinate transformation to an isotropic form. Since we shall rely on this proof to justify using Newtonian methods to develop the line element transformations connecting observers in different gravitational fields, the formal basis for the present model is secure only up to the N-body time independent case, for which a scalar ϵ is sufficient. Of course, this does not imply that Newtonian methods are not available in the N-body time dependent case.

Second, RMIs for the dominant phenomenological theory, the General Theory of Relativity (GT), (especially the Schwarzchild

[2]For a time independent theory of gravity. The general, time dependent case requires consideration of a tensor energy-momentum density rather than the scalar energy density used throughout this article.

solution of the Static Spherically Symmetric (SSS) case), are invariably unsatisfactory to the extent that authors, for example [19], find themselves forced to write-in an ungainly and arbitrary looking functional relationship for the characteristic velocity profile in the vicinity of a gravitating mass. Given the "physicalist" motivations behind the development of RMIs, the approach cannot be said to have succeeded until the relation between the size and location of "source" objects and consequent spatial variations in c can be shown to emerge from the same model that deals with the kinematic responses of inertial objects to said variations.

Third, Dicke [20] and Puthoff [21] have used the Electromagnetics formalism, in the context of a medium of variable dielectric constant, to generate an alternative, but observationally satisfactory[3]theory of gravity, which Puthoff (appropriately or otherwise) describes as the "Polarisable Vacuum (PV) representation of General Relativity". These "physicalist" Electromagnetic approaches to gravity are also somewhat related to the "phenomenological" Yilmaz theory of gravity [22, 23, 24, 25]. PV theory generates the characteristic velocity profile from within the formalism, and so it addresses the main problem with other RMIs. However, like the Yilmaz theory, it leads to an exponential metric in the SSS case rather than the familiar (but arguably strange) Schwarzchild metric. We shall show in section 3.2 that this similarity extends to the N-body case, where the two approaches continue to share the same line element and the same N-body solutions. Although these theories are empirically distinct from the GT, they agree with it to first order, and the present state of the observational and experimental evidence is incompetent to distinguish between them.

Ultimately, the main distinction between the dielectric medium models of Dicke and Puthoff and other RMIs is that varying the electrical permittivity affects the structure of manifest interactions as well as the speed of light. To the extent that we should expect the speed of propagation of disturbances to reflect the strength of underlying interactions, this seems the more reasonable assumption, and so we shall adopt, without proof, the usual result from Electromagnetics that the propagation velocity, c, and the strength of interactions both vary in proportion to this scalar. We also implicitly assume that the wave impedance of the medium is invariant (i.e. that μ and ϵ vary together) so that variations in the medium's relevant properties are described by a single scalar. In addition to these assumptions, we shall apply a second major constraint (i.e. in addition to the dynamical constraint already shown to generate Special Relativity), namely that angular momenta are quantised in the usual way, and conserved in gravitational fields.

The development in sections 2 and 3 parallels Puthoff, but uses a direct "Newtonian" method which avoids the dissonance inherent in writing particles into the field equations. Instead of using various heuristics (like the constancy of the fine structure constant) to determine the line element, it is shown to be implicit in the two constraints already stated above. In place of the Lagrangian method for determining the characteristic velocity

[3] Up to the time independent case. They are inconsistent with the only known observation (on the decay rate of the binary pulsar PSR 1913 + 16) that is directly pertinent to the time dependent case. However, both treat the dielectric constant, ϵ, as a scalar, which renders them inapplicable to the time dependent case, as discussed in section 5.

profile in the vicinity of a single gravitating object, we shall show that the exponential metric is effectively an instance of Gauss's Law. Where both Dicke and Puthoff parameterised the source term using the conventional parameter, mass, we shall find that their Lagrangian analyses point to the system self-energy, rather than the mass, as the appropriate basis for the source term - an important distinction because mass and energy are connected by a variable rather than a constant in the dielectric medium RMI context. These steps enable a simple formulation of the N-body case which helps identify the N-body solutions in PV theory.

Examination of the Yilmaz theory (section 3.3) shows that, although it is labelled M_g, the source term variable is actually the same as the system self-energy in PV theory. It seems inconceivable that both the Yilmaz theory and a tensor formulation of the unmodified PV theory could satisfy the necessary curved space conservation laws in N-body interactive situations. Since the Yilmaz theory does claim to satisfy the relevant (Freud and Bianchi) identities, it is more likely than not that the PV theory requires a modification to its source terms. Having said that, the PV theory draws a necessary distinction (in the context of an Electromagnetic basis for gravity) between the inertial mass and the system self-energy, which is absent from the Yilmaz theory. Although the Yilmaz theory fails to draw this distinction (and it clearly should), it is immune to the error for the simple reason that the inertial mass variable does not enter the equations of motion in curved space theories.

After noting in section 4 the useful implications that this approach has with respect to causality, the passage to a time dependent model is briefly discussed in section 5. The restriction to scalar ϵ, or refractive index, is safe only as far as time independent or low velocity models are concerned. In physical wave models, quantum systems at relativistic velocity have anisotropic distributions of the momentum flux at every point ([8] section 4.3), and it is not generally possible, for N-body problems, to remove this with a coordinate transformation. Also, as stated above, the availability of Newtonian methods in non-uniform spaces has only been demonstrated subject to the ability to define a scalar refractive index, i.e. subject to the availability of an isotropic coordinate system. Whilst it is in any case unlikely that a scalar ϵ would suffice for the general case of N-bodies in arbitrary conditions of motion, none of this rules out an extension to the present model, with tensor $\epsilon^{\mu\nu}$, to address the general case.

2 The Metric Transformations

2.1 The Preferred Coordinate System

As with Dicke and Puthoff, the present model has been developed in the context of an underlying flat or ”Newtonian” [20] metric, which brings with it the implication of a preferred frame, a question which Dicke addressed (partially) by reference to the ”cosmological principle” that the remote universe should appear isotropic to his ”Newtonian” (i.e. preferred) observers. We found previously [8], that the only candidate preferred frame that is consistent with relativistic mechanics is the frame identified by a null result for the dipole component of the Microwave Background Radiation (MBR). Consequently, the unit system of the underlying metric used here is defined by the clocks and rulers of observers at rest in the MBR preferred frame. Peebles [26] was the first to recognise this preferred frame.

Subsequent to the publication of [8], new observational data have become available [27], which are decisive in favour of this particular choice for the preferred frame, and which constitute an empirical success of the wave interpretation of relativistic mechanics as against the usual Special Theory. Blake and Wall observed the gross number density of astronomical objects as a function of the direction in space relative to our known MBR velocity, and found that there is an increase in the direction parallel to our MBR velocity and a corresponding reduction in the opposite direction. Quantitatively, the imbalance is just as predicted by the doppler effect for our known MBR velocity. The only plausible explanation for the consonance of these two otherwise independent observations is that both are due to the real movement of the earth, and this is also clearly the only frame that satisfies Dicke's isotropicity condition.

2.2 Angular Momentum Quantisation

In this sub-section, we shall show that the phenomenon of angular momentum quantisation is a consequence of Newtonian methods, when subjected to the two constraints above. Although the result applies more generally, we shall consider only the simplest conceivable physical model subject to the dynamic constraint which also possesses "intrinsic angular momentum". Self-evidently, propagative systems are inherently not well localised in the usual atomist sense of a point particle, but the "point particles" introduced here are merely the first step in modelling widely distributed wave systems - as long as they are finitely distributed we are free to talk about their centres of momentum as the location properties of the respective fields. Therefore, we shall begin by ascribing the various aggregate field properties (the total system momentum, self-energy and so on) to a set of central location properties. An inevitable consequence of this is that we re-introduce action at a distance (into this first level model). In order better to reflect the distribution of momentum/energy throughout a continuous, propagative field, the momenta (and so on) allocated to central location properties here will be referred, in subsection 2.4, to a second level model - a distributed set of location properties which can be interpreted as the location properties of inherently extensive elementary field excitations - i.e. the eigensolutions of the (unknown) post-Maxwellian field equations.

In systems subject to the dynamical constraint, the basic equation of the Newtonian paradigm is:

$$\mathbf{p} = m\mathbf{c} \tag{1}$$

Where m is interpreted as the contribution of the propagative subsystem to the observed inertial mass of the corresponding subatomic particle, and $\mathbf{c}$ is the velocity, a vector in the direction of propagation whose magnitude always equals the characteristic velocity, c. Differentiating gives:

$$\frac{dp}{dt} = c\frac{dm}{dt} + m\frac{dc}{dt} = c\frac{dm}{dt} \tag{2}$$

Following the Newtonian paradigm, the energy, E, is then found by integrating the work done to change the momentum from 0 to p:

$$E = \int_0^x \frac{d\mathbf{p}}{dt}.d\mathbf{s} = \int_0^t \mathbf{c}\frac{dm}{dt}.\mathbf{c}dt = c^2 \int_0^m dm = mc^2 = cp \quad (3)$$

As was shown previously by considering the conservation of linear momentum [8], relativistic mechanics is the logical consequence of constructing variable speed entities (i.e. massive particles) from constant speed subsystems. Here we focus on the second constraint above, namely the quantisation and conservation of angular momentum.

Photons across a wide continuum range of energies all carry the same quantity of angular momentum, h. Similarly, electrons, protons and neutrons have very different self-energies, but the same angular momentum, $h/2$. These (photons and fermionic massive particles) are the two basic kinds of system found in the world and each kind is characterised by the value of its angular momentum quantum - a curious result within the usual (atomist) approach to mechanics. However, just as it explains relativistic mechanics, the dynamical constraint also provides a straightforward explanation for this result. To determine the conditions under which propagative systems quantise the angular momentum, let us consider a rather simple model of a "particle" with intrinsic angular momentum - a two part system comprised of equal and opposite linear momenta, $p/2$, propagating in opposite directions with a central "force" acting on each of the two such that they move in a circle of radius r and frequency ω, with $c = r\omega$. For the moment, let us assume constant $\epsilon = \epsilon_0 = 1$. The Newtonian definition of angular momentum is:

$$\mathbf{L} \equiv \mathbf{p}X\mathbf{r} \quad (4)$$

Since $\mathbf{p}$ is transverse to $\hat{\mathbf{r}}$ in our example, $E = cp \Rightarrow L = Er/c = E/\omega$. Quantising L (i.e. holding L constant for all E) implies $E \propto \omega$ for each kind of system, so that we may write $E = H\omega$ where ω is the system orbital frequency, and H is a constant for each kind of system. Observationally, it is found that, for photons $H_p = L_p/2\pi = \hbar$, whilst for fermions $H_f = 2L_f/2\pi = \hbar$, so we shall write $E = \hbar\omega$ in both contexts, and return to the difference in the energy to angular momentum ratio for the different kinds of system below. Now, were the system to change to a different value of r, the required energy would be:

$$\Delta E = E_f - E_i = \hbar(\omega_f - \omega_i) = \hbar c(1/r_f - 1/r_i) \tag{5}$$

Whilst, according to the Newtonian paradigm:

$$\Delta E = \int_{r_i}^{r_f} \frac{d\mathbf{p}}{dt}.d\mathbf{s} \Rightarrow \frac{dp}{dt} = \hbar c/r^2 \tag{6}$$

So, the first basic result of applying the Newtonian paradigm to propagative systems is that the quantisation of angular momentum implies system binding interactions of the familiar $1/r^2$ kind that are otherwise independent of the system energy - coulomb-like interactions produce quantised angular momenta. Note that the system energy is equal to the work done to bring the location properties from infinity to the given separation.

Although we considered here a restriction to movements on a circle (for which $\mathbf{p}X\mathbf{r} = pr$), this corresponds neither to photons nor to fermionic massive particles. However, the same result - an association between quantised angular momenta and $1/r^2$ coulomb interactions - applies to any context where the ratio of orbital and total propagation velocities is fixed. If we were to take it that movements at constant speed on a circle correspond to spin-2, then it is easy to show first that movements at the same speed on a helix of unit pitch have spin-1 (photons), and second that there exist (somewhat more complicated) closed trajectories on the surface of a sphere which further reduce the effective orbital velocity by another factor of $\sqrt{2}$, providing spin-1/2 systems, and implying $E = \hbar\omega$ in spite of the factor of 2 difference in the angular momentum quanta for photons and massive particles. The details of this are irrelevant to gravity, where the issue of principle importance, to which we now turn, is how propagative systems scale as we vary the characteristic velocity of the medium.

2.3 Metric Transformations in Dielectric Media

The assumption of a dielectric medium, means that we may write the central "force" and characteristic velocity as $dp/dt = \hbar c_0 \epsilon_0/\epsilon r^2$, and $c/c_0 = \epsilon_0/\epsilon$ respectively. Under a step change in ϵ, the interaction is reduced by the factor ϵ whilst (with no corresponding change in the radius) the acceleration, c^2/r required to maintain the orbit would be reduced by a factor of ϵ^2, so the separation and frequency will be lower in the new system. By how much? Let us assume $r_0 \rightarrow r = r_0(\frac{\epsilon}{\epsilon_0})^{-m}$ and $\omega_0 \rightarrow \omega = \omega_0(\frac{\epsilon}{\epsilon_0})^{-n}$. Clearly we require $m + n = 1$, and it remains to solve for m and n. Write for the mechanical energy change:

$$\Delta E = \int_{r_0}^{r} \frac{\hbar c_0 \epsilon_0}{\epsilon r^2} dr \tag{7}$$

Considering adiabatic changes, we may substitute $\epsilon = \epsilon_0(\frac{r_0}{r})^{\frac{1}{m}}$, which gives:

$$\Delta E = \int_{r_0}^{r} \frac{\hbar c_0 \epsilon_0}{\epsilon_0(\frac{r_0}{r})^{\frac{1}{m}} r^2} dr = \hbar c_0 r_0^{-\frac{1}{m}} [\frac{r^{\frac{1}{m}-1}}{\frac{1}{m}-1}]_{r_0}^{r} = \frac{m}{1-m}(\hbar\omega - \hbar\omega_0) \tag{8}$$

Since $\Delta E = \hbar\omega - \hbar\omega_0$, $\frac{m}{1-m} = 1$ and so $m = n = 1/2$. The transformations above are therefore given by:

$$r_0 \rightarrow r = r_0\sqrt{\frac{\epsilon_0}{\epsilon}} \quad \omega_0 \rightarrow \omega = \omega_0\sqrt{\frac{\epsilon_0}{\epsilon}} \tag{9}$$

These metric transformations then fall through to the dimensions and frequencies of all physical systems, including especially clocks and rulers. Since we write $E = \hbar\omega$, the transformation of ω enforces a similar transformation of the self-energy, so:

$$E_0 \rightarrow E = E_0\sqrt{\frac{\epsilon_0}{\epsilon}} \tag{10}$$

This in turn requires a transformation of the inertial mass contributions, m, which we can deduce either from $E = mc^2$, or by writing $L = mr^2\omega =$constant so that:

$$m_0 \rightarrow m = m_0(\frac{\epsilon}{\epsilon_0})^{3/2} \tag{11}$$

This full set of transformations, which *inter alia* defines the line element, is identical to the set heuristically identified by both Puthoff and Dicke. However we derive or deduce them, they are closely related and form a set which must be accepted or rejected as a single package[4]. Whilst the inertial mass change is irrelevant to the body's motion in a given gravitational field (i.e. in the context of phenomenological curved space theories such as the General Theory and the Einstein-Yilmaz variation), this has to raise a question concerning how each quantum system contributes to generating gravitational effects. Once it is accepted that timebase changes induce self-energy changes induce inertial mass changes, the usually assumed (strong) equivalence between active, passive and inertial masses becomes suspect. Ultimately the rather basic question that must be addressed is why we should use mass rather than energy (since they are not the same thing in the present context), as the source term for gravity? We shall find good reasons to consider that the Lagrangian method of Dicke and Puthoff actually identifies the system energy as the more appropriate basis for a source term.

2.4 The Field Energy Density of Celestial Objects

The physical properties (system momentum, self-energy, mass etc) assigned to the central "particles" in section 2.3 can now be referred to volume integrals of the corresponding field densities. We shall discuss here only the field energy density, which will later act as the source term for impacts on the characteristic velocity, but other properties may be dealt with analogously by applying the metric transformations. Any changes in the force field strength of underlying fields must ultimately be implemented by separating fundamental entities across the field, a process which,

[4] A basic issue with the Yilmaz theory is that it effectively equates energy and inertial mass and so accepts only parts of the package, missing the distinction between active and passive masses which becomes relevant in mixed EM gravity situations.

according to the Newtonian paradigm, requires that work be done in proportion to the pre-existing field strength, E_i, and the magnitude, dE_i, and physical extent, Δx, of the change:

$$dW \propto \mathbf{E}_i \Delta x d\mathbf{E}_i \tag{12}$$

Where the field strength, $\mathbf{E}_i$ should not be confused with the system energy, E. Integrating this Newtonian conception of the field increment leads to correspondence (up to a constant) with the result familiar from electrostatics for the relationship between field strength and energy density:

$$\rho_E = \frac{1}{2}\epsilon\mathbf{E}^2 = \frac{\mathbf{D}^2}{2\epsilon} \tag{13}$$

Where $\mathbf{D} = Q\mathbf{r}/4\pi r^3$. To the extent that the observed electric field of a charged particle varies as $1/r^2$, the corresponding underlying field energy density of a charge necessarily varies as $1/r^4$. Note that we do not maintain that the electric fields of isolated charged particles really are exactly $1/r^2$ fields, or that the quanta of angular momentum, are perfectly conserved, but only that a model reality with $1/r^2$ interaction fields invokes a $1/r^4$ energy density. It should be immediately apparent that this prescription is consistent with an $\mathbf{S}_i = \mathbf{E}_i X \mathbf{H}_i$ interpretation of the fields of a charged particle in which the $\mathbf{H}$ fields cancel due to the necessarily balanced movements pertaining to rest particles. We must now show from within the model, i.e. without using Equation 13, that the energy density varies as $1/\epsilon$.

This can be seen from at least two distinct considerations. First, let us write the relationship between energy density and the quantum system self-energy as:

$$E = \int_{r_c}^{\infty} \frac{4\pi r^2 K}{r^4} f(\epsilon) dr = \frac{4\pi K}{r_c} f(\epsilon) \Rightarrow f(\epsilon) = \frac{E r_c}{4\pi K} \qquad (14)$$

Where K is a constant, $\epsilon \neq f(r)$, and r_c is the radius of the central location properties above. We may ignore the region $0 < r < r_c$ on the basis that the system as a whole scales according to the transformations in sub-section 2.3, so that, whether it is significant or not, the integral in the region below r_c remains in proportion to the integral above r_c, and can be absorbed into the constant, K. This form of relationship applies to individual, isolated, non-interacting quantum systems at rest in a flat space of non-unity ϵ. We know from the above that both the system self-energy and r_c, the lower limit of the integration region, vary as $1/\sqrt{\epsilon}$, so the energy density varies as $f(\epsilon) = 1/\epsilon$. Whilst this argument is strictly available only in a space with constant ϵ, the free space value, r_{c0}, is already so small relative to the dimensions of massive objects in all situations of interest (strong and weak fields alike)[5]that, for any practical purpose, the energy density integral can be truncated within a region where ϵ is constant. Note that, in a space of constant ϵ, the energy density of an individual quantum system is such that $\rho_E/\rho_{E_0} = (E/E_0)^2$.

Second, the Little group informs us that quantum systems at rest evolve under the action of members of the group of spatial rotations [28]. If we are to take a distributed approach to the field/particle system, this can only mean that the energy constituting an (isolated, non-interacting) quantum system always propagates transverse to the radial direction. Therefore,

[5]There being no black holes in the exponential metric theories.

irrespective of the form of the relevant field equations, eigensolutions are constrained to exist on the surfaces of spheres of various radii, which induces a phase matching requirement for stable particles, with the implication that the energy of individual eigensolutions varies as $1/r$ in the flat background space. Self similarity of the eigensolutions for different radii also requires that their number density varies as $1/r^3$, which independently reproduces the free space energy density as a function of $1/r^4$.

Now, if we compare a quantum system in free space with the same system after being moved to the centre of a spherically symmetric inhomogeneity in the medium (i.e. such that $\epsilon = \epsilon(r)$) the eigensolutions associated with the radius r in the second case were previously associated, in the free space system, with the radius $r\sqrt{\epsilon(r)}$. In the course of moving from free space to a position centred on the gravitational inhomogeneity, the self-energy of each such eigensolution was further reduced by a factor $\sqrt{\epsilon(r)}$, so the overall field energy density (bearing in mind that self similarity ensures that the number density is invariant) is reduced by the factor $\epsilon(r)$, and we may now write the SSS energy density as $\rho_E = \rho_{E_0}/\epsilon = K/\epsilon r^4$. This result is independent of the functional relationship between ϵ and r, but still restricted to spherical symmetry, although we shall argue later that even this restriction can be removed for dielectric models.

To calculate the energy density distribution for a large "point-like" gravitational body of self-energy E, we now substitute the solution for ϵ identified below for the spherical case, which is in the general form $\epsilon(r) = e^{2A/r}$. Since the massive object is actually distributed, and the value of ϵ experienced by a given quantum system is overwhelmingly due to other nearby systems, it is meaningless to set the lower limit of integration equal to r_c, and, following Yilmaz, we shall consider the limiting behaviour as $r \to 0$. The system energy is:

$$E = \int_{r\to 0}^{\infty} \frac{4\pi r^2 K e^{-2A/r}}{r^4} dr = \frac{4\pi K}{2A}[e^{-2A/r}]_{r\to 0}^{\infty} = \frac{4\pi K}{2A} \qquad (15)$$

Which fortunately does not diverge as $r \to 0$. Having associated a finite energy with a singularity, the N-body solutions identified below can be used to model more realistic mass distributions. Since each quantum system is embedded in a region of effectively constant, but non-unity ϵ, the self-energy of the massive object is $E \simeq m_0 c^2/\sqrt{\epsilon_{max}}$, where $m_0 = \Sigma_i m_{0i}$ and the m_{0i} are the free space values of the individual particles constituting the gravitational mass. However, we are not usually interested in what the mass of a celestial object would have been if it were divided into elementary quantum systems, so we shall take $K = AE/2\pi$ and the energy density as:

$$\rho_E = \frac{AE}{2\pi}\frac{1}{\epsilon r^4} \qquad (16)$$

The treatment here is analogous to [22], Equations 14, 21, 38 and 39. The result is only as good as the use of a singularity to represent a celestial object, and does not apply to individual sub-atomic particles in a curved space. However, since this assumption is common to all present theories of gravity, and since the intention is to model the theories as opposed to merely the observables, we shall adopt it without further comment except to mention that the form of Equation 16 (i.e. with $\rho_E \propto E^2$ for a singularity) is common to both PV (Dicke and Puthoff) and the Yilmaz theory. It is a consequence for the static limit of the usual demand for scalar gravitational waves, which is the usual assumption made when writing down a Lagrangian density for the scalar field in any form akin to Puthoff's $L_d^\epsilon = \lambda f(\epsilon)((\nabla\epsilon)^2 - \epsilon^2(\partial\epsilon/\partial t)^2)$.

Interpreting the energy density used in this article as a measure of the underlying movements required to sustain quantum systems suggests that an analogy to Gauss's Law, only with distributed source terms, might provide a suitable method for generating the required variations in the characteristic velocity. The most obvious candidate relationship is:

$$\nabla^2 c(r) = \kappa\rho_E \tag{17}$$

Because, when the energy density takes the form of Equation 16, this equation has exponential solutions that can be paramaterised to fit the weak field observational data. Let us test the extent to which it is consistent with the PV theory.

3 The Characteristic Velocity Profile

3.1 The Static Spherically Symmetric (SSS) Case

Puthoff proceeds from the metric transformations to write down each of the different contributions to the Lagrangian density, and then uses the standard method to produce general equations governing the mixed EM-gravity case. Since we have no reason to question either the Lagrangian method *per se* or his prescription for moving from the transformations to the corresponding (static case) Lagrangian densities[6], the outputs of this process should also be valid from the current perspective, as good as the combination of the input transformations with Maxwell's Laws. The purpose here is to identify the role of the energy density in the theory. Limiting the general equations to the SSS case provides an equation for the characteristic velocity profile in the vicinity of a single massive object at rest, the solution of which is an exponential profile, in the general form:

$$c(r) = c_0 e^{-A/nr} \tag{18}$$

However, the Lagrangian method provides at best limited insight into the physical basis for this outcome, relies on a formalism with point charges written in, and masks what we shall argue is a flaw in the choice of the constant A above. Upon limiting Puthoff's general equation for the dielectric constant, Eq 34 of [21], to the static case, choosing units such that $\epsilon_0 = 1$, and changing notation from his $c(r) = c_0/K(r)$ to the present $c(r) = c_0/\epsilon(r)$ we have:

$$\nabla^2\sqrt{\epsilon} = \frac{\sqrt{\epsilon}}{4}(\frac{\nabla\epsilon}{\epsilon})^2 \tag{19}$$

Substituting $F(r) = \epsilon(r)^n$ (where $n = 1/2$ here), and using $(\nabla\epsilon)^2 = 4\epsilon(\nabla\sqrt{\epsilon})^2$ this becomes:

$$\frac{2}{r}\frac{dF}{dr} + \frac{d^2F}{dr^2} = 1/F(\frac{dF}{dr})^2 \tag{20}$$

for the SSS case. The solution of Equation 20 is $F = e^{A/r}$, so $\epsilon = e^{A/nr}(= e^{2A/r})$. The LHS is $\nabla^2 F(r)$, and this general form

[6] The only freedom of relevance being Puthoff's choice ([21] equation 31) of the arbitrary function multiplying the scalar wave Lagrangian density, $f(K) = 1/K^2 = 1/\epsilon^2$, which eventually determines the exponential metric.

of equation should be open to an interpretation by analogy to Gauss's Law, which states that the volume rate of production (consumption) of the flux of the gradient of the function, i.e. ∇^2, equals a source (sink) density. So, we might anticipate finding a recognisable source term on the RHS, but this is not yet obvious. Put $F = e^f$. Then the RHS is equal to $F(\frac{df}{dr})^2$, rendering the solution, $f = A/r \Rightarrow F = e^{A/r}$ more obvious, whilst the RHS becomes A^2F/r^4.

We found above that the energy density at radius r in a spherically symmetric curved space is $\rho_E \propto 1/\epsilon r^4$, so the equation with $n = -1$ should have the energy density on the RHS. Using Equation 19 with the identity $\nabla^2(\epsilon^n) \equiv n(n-1)\epsilon^{n-2}(\nabla\epsilon)^2 + n\epsilon^{n-1}\nabla^2\epsilon$ gives a family of equivalent equations for different values of n:

$$\nabla^2\epsilon^n = n^2\epsilon^n(\frac{\nabla\epsilon}{\epsilon})^2 \tag{21}$$

The equation for $n = -1$ is then:

$$\nabla^2\frac{1}{\epsilon} = \frac{1}{\epsilon}(\frac{\nabla\epsilon}{\epsilon})^2 \tag{22}$$

Which, for the SSS case, is equivalent to:

$$\nabla^2\frac{1}{\epsilon} = \frac{4A^2}{\epsilon r^4} \tag{23}$$

Which also has the solution $\epsilon = e^{2A/r}$, and has the same overall effect as Equation 20. This is identical to Equation 17 with $\kappa = 8\pi A/E$. If we are to admit an interpretation by analogy to Gauss's Law, κ must be a system energy independent constant, so we must choose $A = GE/c_0^4$, rather than $A = Gm/c_0^2$, to conform with the weak field observational evidence, which gives

$\kappa = 8\pi G/c^4$, with c a constant. Note that the symbol, c, for the characteristic velocity is a variable only in Equations 18 and 17, where this has been emphasised by writing $c(r)$.

In section 2 we established associations, first between quantised angular momenta and $1/\epsilon r^2$ force fields, and then between $1/\epsilon r^2$ force fields and $1/\epsilon r^4$ energy densities. The association identified above, between $1/\epsilon r^4$ distributed source terms and the exponential profile for ϵ, closes the loop such that the model generates observationally satisfactory variations in the characteristic velocity from within. Let us now apply this association to the N-body case.

3.2 The N-body Time Independent Case

Although Equation 17 above arose in the context of an SSS problem, it is a local equation (expressed in point form) and thus one might expect it to be independent of the source configuration. Hence we shall try the same equation, $\nabla^2 c(r) = k\rho_E$, in the general case of N bodies, where the main issue is the non-linear superposition of energy densities. The concept of energy we are using in this model - it is a measure of the amount of movement involved in sustaining the quantum system - is contextual because it depends on a property of the medium as well as intrinsic properties of the system. However, even in a medium of varying dielectric constant, the displacement fields, $\mathbf{D}_i$, always superpose, and the square of the displacement density is a true $1/r^4$ field, irrespective of the dielectric constant. Therefore let us separate the SSS energy density, $K/\epsilon r^4$, into its medium dependent, $1/\epsilon$, and system dependent, K/r^4, parts, and rewrite the energy density by analogy to the usual displacement field concept in the form $\rho_E = \kappa' \mathbf{d}^2/\epsilon$, where $\mathbf{d}$ is a true $1/r^2$ vector field.

Now, in order for the notion of an Electromagnetic basis for mass to make sense, especially in the context of the projection postulate in quantum mechanics, the neutron, for example, must be considered to have a non-vanishing field energy density. That is, we must consider neutral entities to consist of positive and negative underlying charge constituents, and we must consider both kinds of field to exist, even when their superposition vanishes, as in the case of the neutron. So the energy density for neutrally charged entities, including celestial objects, will be in the form $\rho_E = \kappa'(\mathbf{d}_+^2 + \mathbf{d}_-^2)/\epsilon$, where the $\mathbf{d}_+$ relate to "sources" of positive charge, and similarly for the $\mathbf{d}_-$. There are then two main possibilities for the energy density in an N-body problem in gravity, namely:

$$\rho_E = \frac{\kappa'}{\epsilon}\Sigma_{i=1}^N[(\mathbf{d}_{i+}^2) + (\mathbf{d}_{i-}^2)] \tag{24}$$

And:

$$\rho_E = \frac{\kappa'}{\epsilon}[(\Sigma_{i=1}^N \mathbf{d}_{i+})^2 + (\Sigma_{i=1}^N \mathbf{d}_{i-})^2] \tag{25}$$

If the analogy to Gauss's Law is be carried forward, then, following the same process as in the preceding sub-section, the N-body solution to Equations 21 and 22 should reduce both sides to one of these two forms. This line of reasoning has been helpful in identifying the following N-body solution of the PV equations:

$$\epsilon = e^{\frac{2G}{c^4}(\Sigma_{i=1}^N \frac{E_i}{r_i})} = \Pi_i \epsilon_i \tag{26}$$

Where $\epsilon_i = e^{2GE_i/r_i c^4}$, the E_i are the observed self energies of the various gravitating bodies, and $r_i = |\mathbf{r}_i|$, where $\mathbf{r}_i$ is the position vector to the i^{th} body. Substituting this solution into Equation 22 brings both sides to $(\frac{2G}{c_0^4})^2 \frac{1}{\epsilon}(\Sigma_i \frac{E_i}{r_i^3}\mathbf{r}_i \cdot \Sigma_j \frac{E_j}{r_j^3}\mathbf{r}_j) = (\frac{2G}{c_0^4})^2 \frac{1}{\epsilon}(\Sigma_i \frac{E_i}{r_i^3}\mathbf{r}_i)^2$, which corresponds to the second option above, Equation 25. Note that the N-body field equation in PV theory is the same as for the SSS case, and that the solution is independent of the present model.

It is interesting to notice that this form for the energy density can vanish (for example at the mid-point between two objects of equal mass). On the one hand, to make sense of an Electromagnetic basis for mass, the underlying fields of different kinds must be taken to exist separately, on the other, when combining fields of the same kind we perform the vector addition before the inner product, as would normally be expected with vector fields. Therefore, the implication of Equation 25 is a real physical superposition of fields of the same kind so that the actual activity in the medium reflects the whole field rather than each of its individual parts taken separately. The effect of this is to give the field concept in our physical model an intrinsic ontological status, independent of any lower level implementation that might address how the fields are instantiated in the medium, so that the model has become non-separable.

This is very relevant because it appears to be logically impossible to remove interaction at a distance from a physical model without such a feature (see section 4 below). Another implication of the non-separability of the expressions above is that we cannot strictly define the self-energy of any one body in terms of an integral over all space of its field energy density, but only the self-energy of the entire system of N bodies. However, as we saw in the discussion following Equation 14, the approximation involved in connecting the observed self-energy of a body with the integral over its field energy density is adequate for any practical purpose. To redefine the source terms on the basis of invariants identifiable within the model would take the physical model beyond its proper context of a discussion of the existing theory[7], so let us continue with this issue of the source terms as it applies to the PV theory.

3.3 Equivalence Principles

Having deduced the exponential form for the SSS characteristic velocity profile, Dicke and Puthoff each proceeded to use the usual parameter, mass, to specify the constant, $2A$, multiplying $1/r$ so as to reproduce the available (weak field) data, and hence wrote the line element [21], Equation 22, as:

$$ds^2 = g_{ij}dx^i dx^j = e^{-2Gm/rc^2}c^2dt^2 - e^{2Gm/rc^2}(dr^2 + r^2d\theta^2 + r^2 sin^2\theta d\phi^2) \tag{27}$$

Where c is the background value (which always equals the locally observed value). The distance, r, in this formula is the "real" or underlying value, i.e. expressed in the unit system of remote observers in background space, which is not generally equal to the locally observed value. Similarly, the mass here must be expressed from the same perspective of remote observers. Recalling that inertial mass increases as $\epsilon^{3/2}$, it seems

[7]It is one thing to build a physical model of a target theory to test whether the theory is physically reasonable, but quite another to use an inevitably metaphysical system directly as the basis for theory.

strange that, as the medium saturates, the efficacy of the source term associated with a given gravitating body should increase rather than decrease. This qualitative consideration is sufficient only to raise a question whether an alternative parameterisation might not be preferable, however the Lagrangian derived mathematics is decisive with respect to the current model: the RHS of Equation 22 is not in the form of either a mass or a mass density, but in the form of an energy density. No other value of n has a feasible[8]field density on the RHS. To be consistent with this equation, the only suitable parameter to represent the total quantity of the source is the self-energy of the system, so let us now rewrite the SSS line element as:

$$ds^2 = g_{ij}dx^i dx^j = e^{-2GE/rc^4}c^2dt^2 - e^{2GE/rc^4}(dr^2 + r^2d\theta^2 + r^2sin^2\theta d\phi^2) \tag{28}$$

Where E is the self-energy, and c is a constant. The two expressions above are equivalent in the weak field limit, but diverge in strong fields. Having shown in the preceding section that the PV formalism has similar time independent N-body solutions to the Yilmaz theory ([22], Equations 18 and 19), it is of particular relevance here that the variable Yilmaz uses as source term, M_g, varies as $1/\sqrt{\epsilon}$ (see Yilmaz's Equation 37′). Therefore Yilmaz's source term corresponds to the self-energy used here, and his line element to Equation 28 above, rather than to Equation 27.

Although Yilmaz briefly discusses the (strong) equivalence between inertial and gravitating masses, ostensibly to justify

[8]Putting $n = +1$ in Equation 21 gives an equation with the mass, or inertia, density on the RHS, but the integral corresponding to Equation 15 diverges.

using the usual d'Alembertian equation as the equation of motion, his result is that the observable geodesic trajectories are independent of the inertial mass. The "equivalence" Yilmaz mentions is then between two variables neither of which really enters the theory (when expressed in the curved metric formalism), and the only relevant "equivalence" is the weak equivalence between a gravitational field and an acceleration field, so this is not an issue that invalidates the Yilmaz theory. Now, a central claim of Yilmaz's theory is that it obeys both of the key curved space identities, namely the Freud and Bianchi identities. It is hard to imagine that PV (i.e. even in the static case where scalar ϵ is good) could satisfy the same identities with the same line elements and solutions but different source terms, so the conclusion here is that the Lagrangian analysis of Puthoff and Dicke does not allow a free choice of the source term (as had been assumed by both authors) if we are to respect the usual and reasonable demands for general covariance and conservation laws.

The distinction between active and passive masses is however important in the mixed EM-gravity situations contemplated in the PV theory, and it is only in this context that the difference between the two approaches - not to mention the validity of the strong equivalence principle - can be tested. Although mass may suggest itself as a primary concept from a perspective inherently focused on, and conditioned by, observability, when we construct physical models to reproduce the observables, it is only natural that this should be reversed, that inertial mass should play the role of an effect rather than a cause. Hence it is not necessarily an appropriate basis for the source term, and there is no *a priori* reason to anticipate an equivalence principle of the strong kind in a physical model. None of this mitigates against the curved space formalisms *per se*, however the second major conclusion here is that unification with Electromagnetics (and hence ultimately with quantum field theory) may well require the removal of the usual assumption of a strong equivalence principle.

4 Causality

Gauss's Law is usually interpreted from the atomist perspective of an ontologically real "charged" particle located at some definite place, which is thought of as emitting the "attached" Electric field, so the object is taken to be primary, the field secondary. Perhaps this is the single most blatant metaphysical presumption in all of Physics, because, by presuming this particular sense of causation, it ultimately commits us to a retarded view of interaction, in conflict with observation.

The alternative that we have developed here - that Gauss's Law is just a model, that the "$1/r^2$" field might equally well be the primary reality and the observable "particle" a part of the epistemology rather than of the ontology, and so no more significant than the location property of a field - is of course equally metaphysical, however it has distinct advantages because it is consistent with the growing number of observations on gravity [6, 30] and laboratory experiments [2, 4, 5] that show the epistemology to have a nonlocal character. However, no part of the ontology in the present model moves faster (or slower for that matter) than the characteristic velocity, so the proposition cannot be said to violate local realism. Matter in this kind of local realistic model is inherently not well-localised, and the interactions don't move at all but simply occur wherever distributed ontological systems overlap. The impacts of such interactions upon the respective particle locations are, of course, retarded. Since the far field EM interactions are significant only in the vicinity of each particle, in a two body electrodynamics situation the direct impact of particle A's far fields on particle B's location is for all intents and purposes instantaneous, whilst the reaction on particle A's location, having been mediated by its own fields, involves retardation relative to the site of the interaction (and *vice versa* for the action of particle B's far fields on particle A).

Equation 25 and the N-body PV solution are also consistent with the proposition that emerged in sub-section 2.4 from considering the Little Group to apply to the entire field / particle system, namely that the field propagates transverse to the radial direction. The conventional view, where we think of the field as propagating away from the particle, ends up introducing magical virtual particles that forever carry momentum away from the source (but only when there is a remote interaction). How the momentum of unabsorbed virtual particles is returned to the source remains a complete mystery, every bit as devastating to the Newtonian and Einsteinian conception of local action as the problem of interaction that the virtual particles were supposed to address. The real problem here is, and always was, atomism.

Now, having undermined the causal relationship between particles and fields it should be observed that we effectively reintroduced the same metaphysical error due to the talk in section 2.4 about the number density of eigensolutions "at" some radius r. This ultimately implies that we return to another point model (albeit one in which each location property refers to an inherently distributed elementary field excitation), which seems to provoke an ongoing model recursion. As Bergson observed in some detail at least a century ago [31], there is an inherent problem in the nature of representation, which is torn between the *prima facie* irreconcilable concepts of inherent extension and inherent non-extension. The first, the idea of continuity, is necessary if we are to discuss interaction between objects without merely referring it to a lower level (as is inevitable in a particle theory), but the second, the idea of separability, seems equally necessary if we are to define spatially distinct objects in the first place. Rather than a wave-particle duality, we should better describe this issue as a wave-particle dichotomy.

Bergson did not leave the philosophical problem there, but came down on the side of pure continuity. We can see that he was correct in this because, whilst one can never create pure continuity from a system of isolated points, one can define a system of isolated points from the movements of a continuum (as we have seen in the present model) in such a way as to provide a basis for *effective* separability without introducing separability in any absolute sense. In short, although this is a purely philosophical problem, it is not strictly necessary for the model recursion that might seem to be implied here to go on ad infinitum.

5 Comments on the Time Dependent Case

We can see that the model presented above is explicitly limited to the time independent case from section 4.3 of [8]. In wave models, the momentum flux density of a relativistic particle exhibits a velocity dependent elliptical anisotropicity. Since movement is the basis of the source terms in the model, we can anticipate that such anisotropic movements may have anisotropic impacts on the characteristic velocity. The assumption here of a scalar energy density leads directly to the use of a scalar parameter, ϵ, to describe the medium, but the adoption of a scalar energy density is only safe when the momentum flux density is isotropic, which is to say in the static case. In the time dependent case source terms should be based in a tensor energy-momentum density which implies using a tensor, $\epsilon^{\mu\nu}$.

As Dicke pointed out [20], the state of the evidence regarding gravity is rather weak because we have little or no access to the strong field situations necessary to distinguish empirically between a number of alternate theories. This is especially so when we move from the time independent to the time dependent case. Only a single observation is categorically related to the time dependent case, namely the decay rate of the binary pulsar, PSR 1913 + 16 (although a second binary pulsar has recently been identified). The General Theory provides reasonable, but not especially convincing (at the 1 percent level of accuracy), agreement with observation. PV theory, as Ibison [29] has found, does not. In fact, PV predicts a result that is almost exactly 2/3 of the observed decay rate, prompting Ibison to the reasonable conjecture that the error might stem from the loss of a degree of freedom upon adopting a scalar rather than a tensor form for the refractive index. Although PV is not, in its present form, a candidate dynamic theory of gravity, we saw above that once the PV source term is modified, it closely corresponds to the static limit of the Yilmaz theory. Yilmaz uses what he calls a scalar "potential", ϕ, (because it has the same form as the potential function of Newtonian gravity) for the static case, but found it necessary to employ a tensor for the time dependent theory. Yilmaz's $e^{2\phi}$ corresponds to ϵ here, or equivalently to K in PV theory. In the RMI context, Yilmaz's 2^{nd} rank tensor potential for the dynamic case can be interpreted, by means of a suitable Taylor expansion, as a tensor refractive index of the same rank.

Having said that, as far as wave models in general are concerned, we already know that the Lorentz Transformation, $dx^{a'} = L^{a'}_{a} dx^{a}$, connects the coordinate systems of different inertial observers in wave models with a characteristic velocity. For the static model here, since the $A^{b''}_{b'}$ are determined by the given metric tensors, we have fixed the transformation $dx^{b''} = A^{b''}_{b'} dx^{b'}$, that connects the coordinate systems of co-moving observers inside and outside a gravitational field. A complete theory should therefore be available consistent with the general transformation $dx^{b''} = A^{b''}_{n'} L^{n'}_{a} dx^{a}$.

With specific reference to physical models as opposed to theory, there are then several problems. In many body problems, no transformation would exist to render the metric isotropic, and the proof [17] of the availability of Newtonian methods in curved spaces (upon which we have relied from the outset) would cease to apply. This does not necessarily invalidate the use of such methods, but it does weaken the otherwise firm formal basis for assuming a Netwonian-like paradigm. Another consequence of changing from a scalar to a tensor form for the dielectric constant, is that the usual scalar concept of charge should be replaced by a vector concept, such that spinning, propagating fields carry one of two kinds of "charge" in correspondence with the two senses of the angular momentum vector relative to the direction of propagation, but there is nothing corresponding to this in the present theory. Due to the self-evident fact that it is objectively meaningless to construct physical models of the reality itself, it is vital that physical models (in the sense contemplated here) should be restricted to interpreting pre-existing physical theories. Overall, whilst a model for the time dependent case is entirely feasible, the theoretical framework within which to conduct such a development must first be clarified.

6 Conclusions

Observationally, although significant advances have been made in the last forty years, Dicke's statement concerning the poor state of the evidence on gravity still holds. The available binary pulsar data may be sufficient to rule out his particular (scalar dielectric constant) approach to an Electromagnetic theory of gravity, but the (~ 1 percent) level of accuracy available without knowing the orbital eccentricity is hardly sufficient to distinguish between the GT and a range of other candidate theories. This may improve as more binary pulsars are discovered, but the ongoing absence of direct, strong field data means that gravity will remain (in practice as well as in principle) an open problem for quite some time to come.

Within this context, it is relevant to notice that the GT is not without its own internal "issues". For example, it is self evident that N-body interactive dynamics problems cannot be formulated in the context of a test particle theory such as Einstein's General Theory of Relativity, so the GT is not a complete theory of gravity, even in the Classical limit. Yilmaz [25, 23] (although this remains the subject of controversy), has also shown that the usual field equations cannot simultaneously satisfy both the Bianchi and Freud identities (the Freud identity guarantees conservation of the 4-momentum in curved space theories) except in 1-body metrics, with the effect that the General Theory fails to provide an acceptable correspondence limit with the Special Theory. Moreover, despite great effort having been expended on the problem, quantum gravity remains a significant challenge and the General Theory remains unquantisable and isolated from the rest of Physics. These facts, and others, constitute a strong motivation to consider alternative theories, but the present model is not to be construed in any such sense. Rather, it should be considered (in the first place) as a discussion concerning certain existing theories and the opportunities they hold. Apart from providing an especially simple formulation which enables solution of the N-body problem in PV theory, the physical model shows just how close the relationship between the PV and Yilmaz theories (from which it was derived) really is, and has hopefully provided some much needed insight into the empirical differences regarding source terms, exposing along the way the lack of self-evidency of the strong form of equivalence principle. Just as none of the criticisms above invalidates the GT, the failure of PV in the case of the binary pulsars does not rule out a generalised dielectric model.

In the second place, we have seen how Newtonian mechanics, when consistently applied to propagative systems, integrates Electromagnetics, relativistic mechanics, quantisation of the angular momentum, covariant gravity and the MBR preferred frame in a simple 3D+t conceptual structure. The distributed source terms identified here, combined with the hypothesis that energy propagates transverse to the radial direction, comprehensively undermine the usual presumption we make concerning causality, namely that interactions are retarded relative to (what we regard as) the physical objects that cause them, removing the often perceived conflict between local realism and EPR [32]. Since we can never know whether a physical model is "true" or "false", the truth value of a physical model is not a relevant consideration, and nor is the uniqueness of a given model. All that is relevant is the availability in principle of physical models, and there seems to be nothing in principle to prevent the construction of relatively simple physical models, including especially physical models within the framework of local realism, that reproduce, and therefore offer physical interpretations of, physical theories consistent with all the observables.

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