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On the Essence of Gravitation and Inertia

Part 1: Inertia and Free Fall of an Elementary Particle

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Abstract

A mass curves space positively. It also senses (is affected by) curvature, created by other masses, and moves accordingly. But how specifically an elementary particle gravitates, i.e., curves space, and senses this curvature are open issues. A related, additional, open issue is its inertia. Our elementary particle model, presented here, enables us to resolve these issues and to show mass to be merely a practicality. In addition, this model yields the axiomatic laws of Newton, and enables us to prove the equivalence of gravitational mass and inertial mass.

Our paper “On the Essence of Electric Charge” shows that an elementary particle curves space by its elementary charge. In Part 2 of this paper we show that, in addition, it curves space by its spin, which induces torsion that results in contraction. This curving is referred to as gravitation. We also prove that gravitational mass is the inertial mass, and extend Einstein’s field equation to become the equation of both energy/momentum and charge/current. With this extension the equation becomes applicable for both the macroscopic and the microscopic reality.

Key Words: Gravitation; Free fall; Elementary particle; Inertia

1 Introduction

Although there have been many attempts to explain gravitation or to present alternatives to General Relativity with its Newtonian weak field approximation, none are based on a model of an elementary particle. An example is “On the Origin of Gravity and the Laws of Newton” (2011), [1]. This theory considers gravity to emerge from the thermodynamic concept of entropy; hence it is “independent of the specific details of the underlying microscopic theory”. It also generates a self-contained, logical derivation of the equivalence principle based on the assumption of a holographic universe.

In contrast, our theory is based on a simple “underlying microscopic” model of an elementary particle.

Some essential elements of our model of an elementary particle are presented in our papers; “On the Essence of Electric Charge” Part 1, [2] and Part 2, [3]. Reading these papers contributes to the understanding of this paper. It also raises confidence in our model, since in these papers we are able, for the first time, to derive theoretically and calculate accurately the radii and masses of the electron/positron, muon/anti-muon and quark/anti-quark.

Our **program** is as follows:

- Construct a simple model of an elementary particle.
- Show that inertia is an intrinsic feature of this model, depending on energy and structure alone.
- Based on this model, derive Newton’s first and second laws.
- Show that mass is not a fundamental attribute of an elementary particle, but just a practicality.
- Show how an elementary particle senses curvature and moves accordingly.

- Derive the universal Newtonian gravitational force and prove the equivalence principle.

2 On Our Geometrodynamic Model (GDM) of Reality

The following introduction to the GDM enables a better understanding of our arguments and derivations.

The current paradigm, despite the successes of the excellent theories that construct it, quantum mechanics included, is facing many obstacles. Many principles remain unproven, attributes of elementary particles cannot be derived and calculated, and mysteries are unresolved. This situation results from the lack of a deeper theoretical layer.

In order to provide this missing underlying layer (substratum), we have constructed, during the last twenty five years, a realistic and tangible theory - the GDM. This layer, the GDM, provides an answer as to what is charge, what is an elementary particle, and relates to additional fundamental subjects.

The need for a “deeper theoretical layer” is exemplified by Hartle [4] in his book “Gravity” p 482: “The Einstein equation relating curvature to density of mass-energy is a fundamental equation of classical physics. **It cannot be derived**, for there is no more fundamental classical theory to derive it from.” The GDM is exactly the required theory that in Part 2 enables us to derive Einstein’s equation.

The GDM Idea

The Elastic and Vibrating three-dimensional Space Lattice is all there is.

Elementary Particles are Transversal or Longitudinal Wavepackets of the vibrating space.

The Units of the GDM

In the GDM all units are expressed by the unit of length L (**cm**) and the unit of time T (**sec**) only. (A conversion from the **egs system** of units to the GDM system and vice versa is possible).

The Constants of Nature According to the GDM

$c_T = c$	Velocity of transversal Space vibrations (EM waves)	$[c_T] = LT^{-1}$
$[c_L]$	Velocity of longitudinal Space vibrations ($c_L > c_T$)	$[c_L] = LT^{-1}$
\hbar	Planck Constant	$[\hbar] = L^5T^{-1}$
G	Gravitational Constant	$[G] = T^{-2}$
α	Fine Structure Constant	$[\alpha] = 1$

Note that according to [3]: $[v]=LT^{-1}$, $[a]=LT^{-2}$, $[H]=[G]=T^{-2}$, $[Q]=[M]=L^3$, $[E_E]=[E_G]=LT^{-2}$, $[\varphi_E]=[\varphi_G]=L^2T^{-2}$, $[F]=L^4T^{-2}$, $[U]=L^5T^{-2}$.

Note that $c_L/c = \pi/2 \cdot (1 + \pi \alpha)$, see (25) in [3], and we can exclude c_L from the list. A more systematic approach would take c_L rather than α to be a constant of nature.

“Rest” and Motion in the GDM

Every disturbance in space must move at the velocity of its elastic waves, c_L or c_T . As a consequence there is no state of rest. “Rest” is defined, therefore, as a situation in which a disturbance, although moving at velocity c_L or c_T , is on a closed track. This orbital movement, Dirac’s Zitterbewegung [5], is the spin of elementary particles. A “translational” motion at a constant velocity v , relative to space, is the moving of a wavepacket, of **constant length**, on a spiral. The “translational” motion is thus the motion of the virtual center of circulation of the wavepacket. An accelerated motion is that on a spiral, with an ongoing contraction of its radius.

Space in the GDM is a Special Frame

Space is a special frame, and velocity and acceleration relative to it are measured by the Cosmic Microwave Background (CMB) Doppler shift. The Special Theory of Relativity in the Lorentzian interpretation is encompassed within this idea.

The GDM is Based on the Theories of Elasticity and Riemannian Geometry

The geometry of a deformed elastic space lattice is Riemannian [2]. We thus conclude that General Relativity (GR) is not only a theory of bent manifolds of a continuous space, but also a theory of deformed elastic three-dimensional space lattices and four-dimensional space-time lattices [2], [3].

Since this paper has a specific purpose we do not elaborate on the GDM, but simply point out, whenever necessary, its relation to the present work. This work, however, exposes the reader to the ideas and way of reasoning of the GDM.

3 Inertia

3.1 “Rest” and Motion

According to the GDM every space disturbance, a transversal or longitudinal wavepacket, must move at the velocity c_T or c_L , respectively. We distinguish between c_T and c_L when necessary and according to the case. In most cases we use the symbol c instead of c_T .

“Rest”

In the GDM we relate to “rest” as the case in which a wavepacket moves in a closed loop. In this case we consider the geometrical center of the circulating wavepacket as its location at rest in space.

The electron (positron) at rest is a circulating longitudinal dilational (contractional) wavepacket with a tangential velocity of propagation c and radius of circulation R_0 . In [3] we

elaborate on this circulation which is actually more complex. Thus, from a distance, the electron (positron) is observed as if at rest, and from close, as a volumetric dilation (contraction), which is its negative (positive) charge that moves in a circle [2] [3].

Fig. (1) is a simplistic description of the electron (positron). The gray sphere (circle) represents the zone of dilated (contracted) space, which is the electric charge. In this discussion we omit, for simplicity, the circulation of the charge, with radius r_e around its surface, as shown in the detailed model in [3]. We also do not show in Fig. (1) that the circulation plane is **not** perpendicular to the velocity vector \mathbf{v} . The projection of the angular momentum \mathbf{L} , of this circulation, on \mathbf{v} is $L_z = 1/2 \hbar$ whereas $L = \hbar\sqrt{j(j+1)} = \hbar\sqrt{1/2(1/2+1)} = 0.866 \hbar$, hence the inclination of the circulation plane.

“Rest” is described on the left of Fig. (1). The zone of dilated space (charge) of our electron revolves, in the xy plane, around the origin with a radius R_0 . In this case: $c = \omega R_0$. From now on, when we relate to the electron we also relate to the positron, unless otherwise is mentioned.

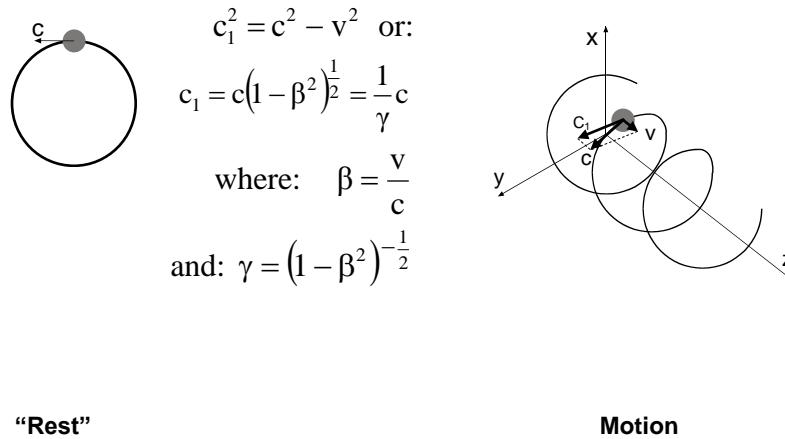
The electron model, presented here, is a simplified version of a much more detailed model that appears in [4] and yields accurately the leptons masses and some other features.

Motion

Fig. (1), on the right, describes motion. Motion is the situation in which the circle of revolution of the wavepacket becomes a spiral. The GDM considers the **length of the wavepacket** to be retained. From this conjecture alone we derive the results of the Special Theory of Relativity. Hence the spiral radius R is smaller than R_0 . This is in analogy to a stretched spring. According to Fig. (1):

$$R = 1/\gamma R_0 \tag{1}$$

The resultant electron motion, however, is always at the wave velocity c . Thus a translatory motion at constant velocity, v , does not involve any exertion of force. It is also obvious that necessarily $v \leq c$.



$$c_1^2 = c^2 - v^2 \text{ or:}$$

$$c_1 = c(1 - \beta^2)^{\frac{1}{2}} = \frac{1}{\gamma} c$$

where: $\beta = \frac{v}{c}$

and: $\gamma = (1 - \beta^2)^{-\frac{1}{2}}$

Fig. (1) Rest and Motion

Newton’s first law, and the first postulate of the theory of relativity, which implies that no particle or signal can move at a speed that exceeds the light/wave velocity c , are thus a natural result. The helical motion, which is an electric current formally in the direction $-z$, is related to the magnetic field \mathbf{B} and the vector potential \mathbf{A} . The Circular Track is stable since the centrifugal force is balanced by an equal but opposite centripetal force. The Lorentz force, created by the magnetic field of the circulating charge acting on itself, is the required centripetal force, see [3].

3.2 The Elementary Particle Inertia

At rest, the energy of the electron is U_0 , linear momentum is $P_0 = U_0/c$ and the angular momentum is $L_0 = P_0 R_0$.

In motion, energy, linear momentum and angular momentum are U , $P = U/c$ and $L = PR$ respectively.

The conservation of angular momentum $L = L_0$ (which is $1/2\hbar$ for the electron) implies that:

$PR = P_0R_0$ hence $UR = U_0R_0$ but:

$$R = 1/\gamma \cdot R_0 \quad (1)$$

Thus:

$$U = \gamma U_0 \quad (2)$$

Considering the energy as purely electromagnetic, where the elementary charge Q is a sphere of radius r_0 [1] [2], the relations $U_0 = Q^2/2r_0$, $U = Q^2/2r$ and (2) give:

$$r = 1/\gamma \cdot r_0 \quad (3)$$

For $v \ll c$ (3) is:

$$r = (1 - v^2/2c^2) r_0 \quad (4)$$

Acceleration is accompanied by an increase of energy U , and a reduction in the radii R and r . The applied force, needed to accelerate the particle, is doing work to curve space more strongly [2], [3] and thus to reduce r . This force is needed to increase stress and cause more strain in order to enlarge the curvature. Thus we arrive at **Newton's Second Law** and understand **Inertia**.

Note that we have replaced Newton's axiomatic laws by our postulated model of an elementary particle. Some of the merits in this replacement, as we show, are:

- It leads to the proof of the equivalence of gravitational mass and inertial mass.
- It enables us, Part 2, to show that gravitational mass is inertial mass.
- It proves that mass is not a fundamental attribute of matter.

- It proves that inertia is an intrinsic attribute of matter, with no need for an additional field to induce it (Higgs Field).

Note that $L = 1/2 \hbar$, $R = 1/2 \hbar c / U$, $U_0 = Q^2 / 2r_0$ and $r = Q^2 / 2U$ give:

$$\alpha = r/R = Q^2 / \hbar c \quad \textbf{Fine Structure Constant.}$$

Note also that at “rest” the angular momentum can point in any direction, whereas in motion it can point, generally (see Section 3.1), in the direction of motion or opposite to it. This attribute is related to Space Quantization.

3.2 Mass

Our “relativistic” relation (2) gives:

$$U = \gamma U_0 = U_0 \left(1 - \frac{v^2}{c^2} \right)^{-\frac{1}{2}} \approx U_0 + \frac{1}{2} \frac{U_0 v^2}{c^2} \quad \text{The second term: } \frac{\frac{1}{2} U_0 v^2}{c^2} = \frac{1}{2} (U_0 / c^2) v^2 ,$$

is identified as the **kinetic energy** where:

$$M_0 = U_0 / c^2 \tag{6}$$

Thus **inertial mass** becomes merely a **practical term**. We also get:

$$M = \gamma M_0 \tag{7}$$

The literature distinguishes between the **kinetic energy** $\frac{1}{2} M_0 v^2$, which a particle possesses by virtue of its motion, and its **internal energy** $M_0 c^2$. But here, the kinetic energy is also an internal energy of deformation (the reduction in size of r and R) that cannot be distinguished from the rest energy.

Note again that the electron model, presented here, is a simplified version of a much more detailed model that appears in [4] and yields the masses of the leptons and quarks.

More on our electron is presented in:

Appendix A - The Angular Velocity of the Electron

Appendix B - The Moving Electron - Supposedly a “Point-Like” Particle

Appendix C - Disintegration and Radiation of and by the Electron

Appendix D - A Note on Special Relativity (SR)

4 How an Elementary Particle Senses Curvature and Moves Accordingly

We contend that the curving (deforming) of space creates gradients in light velocity, see the textbook [6]. This is in contrast to the common understanding that light velocity, even in a gravitational field, is constant, and it is the rate of time that is affected by gravitation, see [6] and our Appendix E and F. We further contend that an elementary particle, being a longitudinal circulating wavepacket, with a given radius, can “detect” these gradients and move accordingly - to fall free. In this regard we do not have to relate to gravitation as a force field.

4.1 The Gravitational Field as a Gradient in Light Velocity

General Relativity (GR) is about space being curved positively around gravitational masses. But Riemannian geometry is not only the geometry of **curved manifolds**; it is also the geometry of **deformed spaces** [3]. Hence curving can be considered the contraction of space around a mass, see Schwarzschild solution [6]. In this case, space close to a mass is more contracted than that at a distance, and hence the positive deformation (curving) of space. Length, close to a mass, is smaller, and the rate of a clock is slower, than at a distance.

Let P be a point in an empty and static space and P_1 a point, which is a distance r from P . An additional point is P_2 ; on the same line PP_1 and same side as P_1 and a distance $r + dr$ from P .

The introduction of a mass M at a point P contracts space around the point. The distance from P to P_1 is now $r' < r$ and from P to P_2 it is $(r' + dr') < (r + dr)$ where $dr' < dr$. According to the Schwarzschild metric [6]:

$dr' = \left(1 - \frac{2GM}{rc^2}\right)^{\frac{1}{2}} dr$. For $\frac{2GM}{rc^2} \ll 1$, we get the approximation:

$$dr' = \left(1 - \frac{GM}{rc^2}\right) dr \quad (8)$$

For the surface of the Sun or the edge of our galaxy $\frac{2GM}{rc^2} \sim 10^{-6}$. We now define a gravitational **Local Scale Factor**:

$$a_g(\mathbf{r}) \stackrel{\text{def}}{=} \frac{dr'}{dr} = \left(1 - \frac{GM}{rc^2}\right) = \left(1 + \frac{\phi}{c^2}\right) \text{ where } \phi \text{ is the gravitational potential.}$$

At the surface of the Sun, or at the edge of our galaxy, a_g is approximately $1 - 10^{-6}$. From the definition for a_g we get the relation of ϕ to space contraction: $\phi = c^2(a_g(\mathbf{r}) - 1)$.

Note that $a_g < 1$ hence $\phi < 0$, as it should be. The gravitational potential ϕ is thus a measure of space contraction.

According to our understanding of GR, light velocity is variable, referred to in the literature as VSL. This understanding has many implications discussed in [7]. According to [6] and using c_0 rather than c in the denominator (an approximation):

$$c = c_0 \left(1 + \frac{2\phi}{c_0^2}\right) \quad (9)$$

According to (9) the gravitational potential is: $\phi = \frac{1}{2} \cdot c_0 (c - c_0)$. Note that $c < c_0$. The field strength is thus (we omit the minus sign):

$$\mathbf{E}_g = \frac{d\phi}{dr} = 1/2 c_0 \frac{dc}{dr}$$

$$\mathbf{E}_g = 1/2 c_0 \nabla c \tag{10}$$

Note that $\mathbf{E}_g = \mathbf{g}$ is the free fall acceleration.

Thus the gravitational field can be looked upon as a gradient in light velocity $\mathbf{E}_g = 1/2 c_0 \nabla c$.

Note that c is not a scalar, it is a vector \mathbf{c} , and $\nabla \mathbf{c}$ is a gradient of a vector. This gradient involves Christoffel symbols which are involved in the GR alternative to the classical field.

This is, in a way, a tautology since we used the Schwarzschild metric results for c and dr .

Equating $g = GM/r^2$ to (10) gives:

$$1/2 c_0 \nabla c = GM/r^3 \cdot \mathbf{r} \tag{11}$$

Note that M is a gravitational mass, since it comes from Einstein's field equation.

Note also that our derivation can be looked upon as a weak field approximation of GR, since we use (9) as the basis for our derivation.

4.2 Free fall

Free fall is the result of elementary particles being longitudinal circulating wavepackets. As such they can sense (affected by), as we show, the gradient in light velocity. At large, if in part of the circular trajectory the particle moves with a slower light velocity than in another part, the linear momentum U/c of the slower part increases. In order for the particle to retain angular momentum, $L = (U/c)R$, R should become smaller. This is done by the increase of its translational motion. It is an ongoing process and hence the free fall acceleration. Note that the circulation plane, as explained in Section 3.1, is not perpendicular to the direction of the free fall. This enables the particle to continuously sense the gradient in light velocity while falling down and being accelerated.

From this crude explanation we now proceed to a formal derivation. According to (1) and (2):

$L = (U/c)R = (U_0/c)R_0$ and since the retained L is simply $1/2 \hbar$ we get, by using (9):

$$U = 1/2 \hbar/R_0 \cdot c_0 (1 - GM/rc_0^2) \quad (12)$$

The force is $F = dU/dr$ and the derivation of (12) gives: $F = 1/2 \hbar c_0/R_0 \cdot GM/r^2 c_0^2$ or:

$$F = GM/r^2 \cdot \hbar/2R_0 c_0 \quad (13)$$

Using (5) $U = Q^2/2r_0 = \alpha \hbar c_0 /2r_0 = \hbar c_0 /2R_0$, $U/c_0^2 = \hbar/2R_0 c_0$ and $U/c_0^2 = M'$, where M' is

an inertial mass, (13) becomes: $F = GMM'/r^2$ or:

$$\mathbf{F} = GMM'/r^3 \cdot \mathbf{r} \quad (14)$$

M' in (14) is the inertial mass of the falling particle whereas M is the gravitational mass of the curving mass that creates the gradient in light velocity. Each and every mass falls free in the gradient of light velocity created by the presence of all other gravitational masses.

Let M_1 and M_2 be the gravitational masses of two particles and M_1' , M_2' their respective inertial masses. According to (14):

$F_{12} = GM_1 M_2'/r^2$ and $F_{21} = GM_2 M_1'/r^2$. If $F_{12} = F_{21}$, which is Newton's third law (applicable only for the weak field case in which space translational symmetry holds) then:

$M_1 M_2' = M_2 M_1'$ or:

$$M_1'/M_1 = M_2'/M_2 = \text{constant}. \quad (15)$$

This is a proof of the **equivalence of gravitational mass and inertial mass**.

In Part 2 of this paper we arrive at a proof of their **equality** and not only their **equivalence**.

Note that our proof is free of tautology. We used GR to arrive at the gradient in light velocity, but the ability of an elementary particle to sense this gradient and free fall accordingly, is the result of our model.

This understanding of gravitation opens up a new way to address the issues of Space Expansion, Dark Energy and Dark Matter. These subjects, however, are out of the scope of this paper.

Note, however, that the gravitational force between two masses, that both curve space positively, must be repulsive according to the GDM. Otherwise it cannot comply with the GDM theory of electrostatics, which relates charge to curvature. And, indeed, the Cosmological Constant represents a repulsive force [8], which can be derived from the GR equation using its weak field approximation - Poisson equation. The relevant general field strength or acceleration is:

$$\mathbf{g} = -\nabla \phi = -GM/r^3 \cdot \mathbf{r} + 1/3 \cdot \Lambda c^2 \mathbf{r}$$

Hence at large distances, hundreds of kiloparsecs (kpc) from the center of our Milky Way galaxy for example, the repulsive acceleration becomes larger than the “gravitational” central acceleration.

5 Summary

We have explored the nature of Inertia by constructing a simple model of an elementary particle. This model enabled us to realize that mass is only a practicality and not a fundamental attribute of matter. Based on this we have proceeded to the issue of how a mass senses curvature and moves accordingly. This sensing and moving accordingly is “free fall”, to which we refer as the “gravitational attraction”.

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Appendix A The Angular Velocity of the Electron

In the pair-production process the electron and the positron retain the original angular velocity of the creating photon.

$$\hbar\omega = U_e + U_p = 2 U_e \quad \text{hence:} \quad \omega = 2 \frac{U_e}{\hbar} \quad \text{on the other hand:} \quad \omega_{DB} = \frac{U_e}{\hbar}$$

where ω_{DB} , is the **de Broglie wave frequency**. Hence:

$$\omega = 2\omega_e \tag{A1}$$

On the face of it, we would expect the angular frequency to be the same as the de Broglie angular frequency, whereas here we get the original angular frequency of the photon that created the electron and the positron. This relation (A1) is related to the wavelike quantum mechanical behavior of material particles. Note also the important result:

$$\omega = \gamma\omega_0$$

Appendix B Size of the Moving Electron

Scattering experiments with energies of 10 TeV (at the LEP storage ring), “sets” an “upper limit” of $\sim 2 \times 10^{-18}$ cm for the electron size [9]. In these experiments, the higher the scattering energy, the shorter the distance between the colliding particles (by overcoming the repulsion). According to the GDM the imparted energy, in the experiment, reduces the radius of the electron, and there is no limit to its size, see Fig. (2).

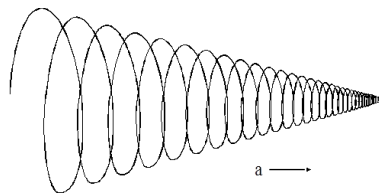


Fig. (2) The track of the Accelerated Particle

Appendix C Disintegration and Radiation of and by the Electron

Considering the electron as a classical particle that can stay at rest, raises the question regarding the electrostatic repulsion that can tear it apart.

In the GDM, however, the electron is a wavepacket that always moves at the speed of light, whether as a closed loop (“rest”) or as an open spiral. Therefore, we should consider the

Lorentz force between the “parts of an electron”, each with charge δQ , that happen to run in parallel and at the speed of light.

The Lorentz force: $\mathbf{F} = \delta Q \left(\mathbf{E} + \frac{1}{c} \mathbf{v} \times \mathbf{B} \right)$ is the force that “one part of the electron”, with charge δQ , applies on “another part”, also with charge δQ , by creating the fields \mathbf{E} and \mathbf{B} . Using the expression $\mathbf{B} = (1/c) \mathbf{v} \times \mathbf{E}$, that defines \mathbf{B} and taking $v = c$, we get $\mathbf{F} = 0$. This result explains stability.

In the “rest” mode, the electron charge moves at a tangential speed c on a closed circle. This might be expected to yield synchrotron radiation, and a loss of energy. But this radiation moves at the speed of light, which is the speed of the emitter and hence can never leave it.

Appendix D A Note on Special Relativity (SR)

We retain the SR formalism, since space is just another frame of reference although it is universal. However, our understanding of what this formalism represents is different from what appears in textbooks.

Appendix E A Note on Light Velocity

For a homogeneous and isotropic space density ρ_0 , far from masses and net charges, light velocity c is a constant, notated c_0 . For a deformed/curved zone of space, with $\rho \neq \rho_0$, a distance from us, the situation is different. For us, Far-away Observers (FO), GR [6] and the GDM show that light velocity is slower close to a mass than at a distance from it.

The GDM considers the space lattice to be an elastic media and its vibrations EM waves [2].

The Navier equation governs elastic media. Its solution for elastic transversal waves gives the expression for light velocity:

$$c = \sqrt{(\mu/m)} \tag{E1}$$

where μ is a Lamé coefficient and m is the mass density of the media. Since space is massless we take m as:

$$m = \epsilon_s / c_0^2 \quad (\text{E2})$$

where ϵ_s is the standard space energy density as we FOs measure, and c_0 is the relevant light velocity (as we measure it). Inserting (E2) into (E1) gives:

$$c = c_0 \sqrt{(\mu / \epsilon_s)} \quad (\text{E3})$$

Thus $[\mu] = [\epsilon_s]$, and we can rename the numerator and use ϵ instead of μ . Thus (E3) becomes:

$$c = c_0 \sqrt{(\epsilon / \epsilon_s)} \quad (\text{E4})$$

By using (E2) we have turned (E1), an equation that determines c , into an equation that determines the ratio c/c_0 . More than that; we suggest considering the ratio ϵ/ϵ_s as the ratio between the energy density ϵ_s (that the FO observer measures around himself), and the energy density ϵ that a Local Observer (LO) measures around himself. Let ρ_0 and ρ be the respective space densities; necessarily:

$$\epsilon / \epsilon_s = \rho_0 / \rho \quad (\text{E5})$$

Space around a mass is contracted, hence $\rho > \rho_0$, and according to (E5) and (E4) $c < c_0$.

Appendix F A Note on Time

We do not know what time is. All we know is that the rate of a clock can be used to define a unit of time. A local clock can be a box with two opposite ideal mirrors that reflect a beam of light back and forth. The time of flight back and forth is our unit of time. This unit of time, according to Lorentz transformation, becomes longer if the box moves parallel to the beam, and/or if it is placed in a gravitational field where light velocity is slower [6]. Measuring time is merely the comparison of the rates of clocks. Time by itself has no meaning for us.

Our time coordinate, in units of distance, is $x = ct$. Relating to our 4D reality as a 3D Space and 1D Time, the following notations are common in the literature; $x_4 = ct$, $x_4 = ict$ or $x_4 = -ict$. It is now clear that we can relate to space density in a broader sense that includes the rates of clocks (time) at each and every point. Density of a space-time lattice, in a zone around a given point, is thus an intrinsic property, which we can measure.

Appendix G Screening

A Faraday cage shields its inside from external electric fields. This is possible since free electrons in the metallic cage create an equipotential surface on the cage and hence the field inside the cage becomes zero. A Faraday cage, however, does not shield an inside mass from the gravitational field because it cannot cancel the gradient in the velocity of light.

Appendix H Free Fall of an Electron

The consensus is that particles should fall freely in a gravitational field regardless of their charges. For neutrons, this is the case [10]. Electrons, however, fall with an acceleration of $0.1g$ rather than g . This result was predicted [11] and demonstrated experimentally [12]. This result is explained by the presence of an electric field, created by the gravitational field and opposing it. This electric field is the gravitational “polarization” of the metallic tube used in the experiment. To date, this is the only free-fall experiment that has been performed on an elementary particle.