Discretization of the Gravitational Field
Part 1: Fundamentals of the compatibility with the electromagnetic field

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The replacement of the vacuum dielectric constant ε_0, in the energy equation of electromagnetic fields, is a key element in any attempt to quantize the gravitational fields that is based on the reality of our Universe and not in a pure conceptual exercise. Usually, the choice falls on the inverse of the Universal Gravitational Constant G. This seems reasonable, since ε_0 has an inverse relationship with the Coulomb constant K, used to determine the force between two charges, just like G does between two masses. But this choice leads to the replacement of the unit charge by a mass not very common in the Universe: the Planck's mass. However, the fine structure found in the Cosmos in the last century and the dimension of Time Crystals found in 2016, seem to differ with this option. The analysis made in this paper, leads to determine a different constant for the replacement of ε_0, more concordant with the cosmological data and Quantum Mechanics.

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A-Introduction

Those who try to develop a common model to unify gravitational fields with electromagnetic ones, face serious problems due to very different and complex mathematical formalisms. The physicist Hans-Jürgen Treder tried to give a physical meaning to the quantization of the gravitational field, using a high-level view that avoids involvement with these formalisms that make it difficult to visualize the natural process that is being described (Treder, H-J.-1979).

Treder began explaining the physical foundations that justify the application of quantum theory to gravitational fields, defining with this process a simple method to find the bases of a new and less complex matching.

This is the method that will be followed in this research, whose main objective is to explain the discretizations found in the Cosmos. It will be based only on existing and proven physical theories and any application of them in a different environment, should be validated with the reality of the Cosmos, when possible in the Solar System, where the necessary data are known with more precision and reliability.

Since it is about explaining "discretizations in the Cosmos", the most appropriate physical theory seems to be Quantum Mechanics, so the first step would be the choice between wave mechanics (First Quantization) and the theory of the quantum fields (Second Quantization).

If the First Quantization is used, the dimensions of the cosmic masses in motion will produce discretizations too small in their orbits, making necessary the formulation of new paradigms, which determine waves of lengths comparable to those of the orbits (Greenberger, D.M.-1983) to allow obtaining quantum numbers similar to those found in cosmic discretizations. This puts this alternative outside the scope of this research, which only uses consolidated physical theories.

The most suitable branch seems to be the Second Quantization, since the discretizations found in the orbital velocities do not depend on the masses of the celestial bodies involved (Pardi J.A.-2019), as it should happen in a theory of quantum gravitational fields.

Another advantage of the field's quantization is that it allows overcoming the substantial difference between the nature of the electromagnetic and gravitational fields, using in its definition elements common to both, such as: energy, volume and time.

But not all are advantages, there are also some difficulties. One of them is that ε_0, the vacuum dielectric constant used to determine the field's energy, uncovers the electromagnetic nature of the definition.

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This obstacle seems easy to overcome, since ε_0 is proportional to the inverse of Coulomb's constant K, the electric equivalent of G, the universal gravitation constant, so there is a general consensus to replace ε_0 with the inverse of G.

But there are also more serious conceptual problems in the application of the logic of the Quantum Fields Theory to the gravitational fields, among them that while the quantum fields are variable in time, the gravitational ones are static.

Fortunately, there are different types of fields in electromagnetism: classical, semi-classical and quantum fields that, under certain conditions, may be related to each other (Berestetskij, V.B et al.-1978). So it is possible to suppose that the same could happen with the gravitational fields, although if, of course, this must be proven.

Specifically, the situation facing this analysis is not that of a pure field, but that of its interaction with a mass. In this case, it is possible to use the theory of The Measurability of Electromagnetic Fields Quantities (Bohr N., Rosenfeld L. - 1933), an application of the Quantum Fields Theory, which starts from classical fields such as the electric one, to reach fields defined by quantum theory, with the support of all its logical and mathematical formalism.

Since this was also the choice of Treder in the publication already mentioned, using this formalism would give the advantage of being able to apply one of its new Uncertainty Principles to the discretizations observed in the Cosmos, to verify the conclusions that are going to be obtained in this study.

Another serious problem from the conceptual point of view is that electromagnetic fields are defined as "the force exerted on a unit of charge". While in electromagnetism the elementary electric charge plays this role, in gravitation does not seem to be an equivalent mass.

Although this mass does not appear explicitly in the equations of the field energy, making it evident becomes necessary to understand some processes.

Replacing the charge's unit by its mass does not solve this problem since there are two elementary charges that meet this condition: that of the electron and that of the proton and, though both of them have the same charge, their masses are different then the issue is which one choices.

Leon Rosenfeld also faced the quantization of the gravitational field, getting to establish the mass of Planck as the minimum acceptable limit (Rosenfeld L.-1965). Treder, on the other hand, did not identify it as a limit, but used it in its new uncertainty principles as a consequence of the Einstein’s Principle of Equivalence.

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Whether Rosenfeld or Treder, they came to the conclusion that it was impossible to prove any quantum theory of gravitation in regions with magnitudes similar to Planck's dimensions. But, as will be seen, this conclusion is a consequence of the wrong use of the inverse of the Universal Gravitation Constant G as a replacement of ε_0.

Rosenfeld, on the other hand, went further, concluding that "*no logical compulsion exists for quantizing the gravitational field; rather the question of whether and how such a quantization is to be carried out can only be decided empirically* "(sic).

Although if all the aforementioned physicists converted the equation of field energy by simply replacing the constant ε_0 by $1/G$, none of them considered the substantial difference between the two fields since the gravitational field is acceleration while the electromagnetic field is not.

Nor did they raise the fact that to quantize a classical field as the gravitational one, it would probably have to have, at least, the properties of a semi-classical field, which could introduce a limitation, no longer in the mass of the test body, but in the generating mass of the field.

These last two omissions have consequences in their conclusions and equations.

Until the end of the '90s the empirical data required by Rosenfeld to try to quantize the gravitational field did not exist, but after this date, they have begun to appear in the gigantic Cosmos laboratory, so it is time to rethink his claim, starting with the analysis that led to the aforementioned conclusion.

B-The Rosenfeld's proposal

Shortly after delivering the theory of electromagnetic field measurement developed with Niels Bohr, Rosenfeld gave a lecture at the NORDITA institute in Copenhagen, which he repeated in 1965 at the Einstein Symposium in Berlin, proposing to relate the Quantum Theory with gravity through the equation of the electromagnetic field energy.

In fact, the average value of a component of the field δF of a photon of electromagnetic radiation of dimension L is determined within the space-time volume defined by its own volume and the inverse of its oscillation frequency ω. Since in a photon $L \approx c/(2\pi\cdot\omega)$, this operation can be performed using the definition of the field energy:

$$\delta E \approx \frac{\hbar\cdot c}{L} \approx \varepsilon_0 \cdot \delta\bar{F}^2 \cdot L^3 \quad \Rightarrow \quad \delta\bar{F} \approx \frac{\sqrt{\hbar\cdot c/\varepsilon_0}}{L^2} \qquad \text{(B.1)}$$

Rosenfeld proposed to begin the analysis of the possible quantization of the gravitational field by replacing in (B.1) the constant ε_0 by the inverse of the Universal

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Gravitation Constant G (Rosenfeld L.-1965), to estimate the photon's field of a hypothetical weak gravitational radiation, taking advantage of the fact that the other variables do not refer to the electromagnetic environment:

$$\delta\bar{g} = \frac{\sqrt{G\cdot\hbar\cdot c}}{L^2} \qquad \text{(B.2)}$$

From this definition it can be determined the energy of the field:

$$\delta E_g = \frac{\hbar\cdot c}{L} \approx \frac{1}{G}\cdot\delta\bar{g}^2\cdot L^3 \qquad \text{(B.3)}$$

When trying to measure the field of this radiation photon, with a test body that uniformly fills the volume L^3, following the reasoning of the theory of measurement of electromagnetic fields quantities, Rosenfeld finds that the measurement conditions impose the Planck mass as lower limit for the test body, without analyzing the impact that the constant G had in the determination of this limit.

It is not difficult to show that the unit of mass implicit in (B.3) is the Planck mass $m_{pl} = \sqrt{\hbar\cdot c/G}$, due to the constant used is just G. Using (B.3) and extracting the square root of the product of the second term by the third:

$$\delta E_g = \frac{\hbar\cdot c}{L} \approx \sqrt{\left(\frac{\hbar\cdot c}{L}\right)\cdot\left(\frac{1}{G}\cdot\delta\bar{g}^2\cdot L^3\right)} = \sqrt{\frac{\hbar\cdot c}{G}}\cdot\delta\bar{g}\cdot L \qquad \text{(B.3.1)}$$

C-Why G is not a good replacement of ε_0

From a purely theoretical point of view, this choice is the right one. Indeed, the choice of ε_0 in electromagnetism is a consequence of accepting that the electric field around a charge stores the work done to assemble it, transporting elementary charges from infinity to its surface.

As shown above, by replacing ε_0 by $1/G$ in the calculation of the energy of a field, it is accepted that the assembly process starts with a Planck mass and continues transporting Planck masses from infinity to its surface. As already noted, this conception is theoretically valid, but it is outside the reality of the Cosmos, where the Planck masses are not representative.

In fact, whereas the elementary electric charge is the fundamental "brick" on which the electric bodies are "constructed", the same cannot be said for the Planck mass that is the product of a theoretical analysis, in addition, much greater than the mass of the fundamental component of the Universe: the Hydrogen atom. This restriction seems very limiting, since it leaves a large range of masses uncovered.

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It was from this and other results of his analysis, that Rosenfeld concluded by suggesting that the question of the quantization of gravitational fields should be decided empirically, that is, by "consulting the opinion of Nature".

Empirics evidences

At the moment, the only empirical evidences of discretization of weak gravitational fields a cosmic scale that could be used for this purpose, are (Pardi J.A.-2019):

1. The Chandrasekhar-Wilson's discretization of the cosmic masses (Pardi J.A.-2019),
2. The lowest limit of the gravitational potential in the cosmic bodies (Wilson A.G.-1968),
3. A discretization at cosmic scale (Agnese A., Festa R. – 1997 y 1998), where arises the universal constant α_g that relates the tangential velocity of the lower energy orbit with the speed of light ($\alpha_g = v/c \cong 1/2086$). Due to its characteristic, Agnese and Festa establish an analogy with the α constant of the fine structure and hence its name. The astronomical or physical origin of this new constant was, before this article, unknown.

Finding the unit mass without using G

Of the few quantum principles proposed by Rosenfeld, it is possible to obtain a couple of conclusions, using data from the Solar System and the discretization at cosmic scale found by Agnese and Festa.

Assuming that the gravitational field is quantized and that in its lower orbital all the celestial bodies are driven by a quanta of weak radiation, it is possible to replace the resulting velocity of the constant α_g ($v_g \approx a_g \cdot c$ = 1,437 10^5) in the impulse equation to find the size L of the lowest orbit's quanta.

Then, the impulse exerted by the field on a unit mass m_u in the interval L/c will be given by:

$$\Delta p \approx m_u \cdot (\alpha_g \cdot c) \approx \frac{\hbar}{L} \qquad \text{(C.1)}$$

Using the condition that the mass must uniformly fill the volume of these hypothetical quanta, it is possible to replace m_u by the equation of the body density. Using the average density of Solar System bodies ($\rho \sim 3 \cdot 10^3$):

$$L \approx \sqrt[4]{\frac{3 \cdot \hbar}{4\pi \cdot \rho \cdot (\alpha_g \cdot c)}} = 1{,}6 \cdot 10^{-11}\text{m} \sim a_0 \qquad \text{(C.2)}$$

The result is quite similar to the neutral H atom's size a_0, in the lowest energy state ($\sim 10^{-11}$).

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The magnitude of m_u can be determined from the average density of the celestial body, since it must uniformly fill the quantum volume L^3:

$$m_u = \rho \cdot \frac{4\pi}{3} \cdot L^3 \approx \sqrt[4]{\frac{4\pi}{3} \cdot \rho \cdot \left(\frac{\hbar}{(\alpha_g \cdot c)}\right)^3} \approx 4{,}7 \cdot 10^{-29} \approx m_p \cdot \sqrt{\frac{v}{c}} \qquad \text{(C.3)}$$

From the results obtained from this empirical evidence resulting from applying to the gravitational field, simple and basic quantum principles of the electromagnetic domain, it is possible to draw two conclusions:

1. ***The value obtained for the mass, leads unequivocally to an order of magnitude more comparable with the proton mass m_p (~ 10^{-27}), than with the Planck mass (~10^{-8}),***
2. ***The dimension L of the hypothetical gravitational radiation quantum has a magnitude more comparable to the dimension of the neutral H atom in its state of lower energy, than to the Planck length or to the dimension of a celestial body.***

Breaking-up the gravitational field

This last conclusion suggests that the action of the quantized gravitational field is not exerted on the totality of the mass of the celestial bodies, at least in their lowest orbital, but on fractions of it.

This leads to suspect that, as in the electromagnetic case, the gravitational field, at least on a planetary scale, does not behave as a classical field, but as a semi-classical one and therefore could be composed of quantum oscillators that obey the Bose statistics (Berestetskij V.B. et al.-1978), as approximately represented in Fig. 1 and 2. Those oscillators, together, would be who are impelling the mass of the celestial body.

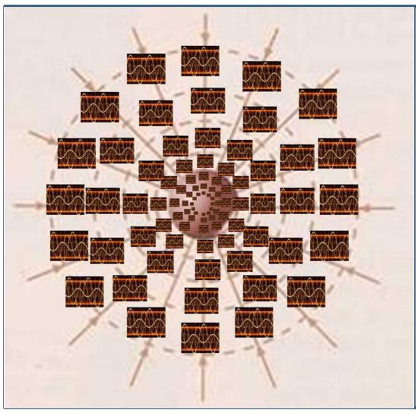

Fig. 1: The field as a set of quantum oscillators
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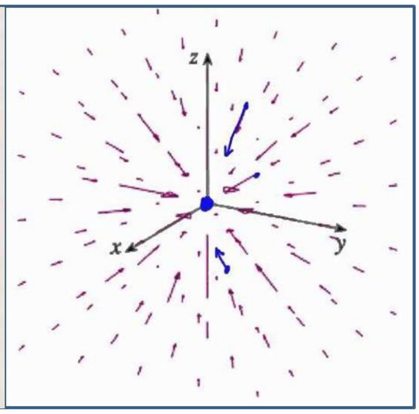

Fig. 2: Oscillators' radial impulse
Picture source: Académica.com

Obtaining the unit mass without using G

The order of magnitude of the mass (~10^{-29}) of the "quantum of hypothetical weak gravitational radiation", which could be associated with that of a "graviton", seems to

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be much higher than that currently attributed (~10^{-48} - K Olive et al.- 2014) and also higher than the inferred from the gravitational waves of the source GW150914 (~10^{-39} - BP Abbott et al.- 2016), even though the latter were deduced from higher energies and, therefore, it should have also a higher magnitude. However, it is encouraging that the new value is 10^9 orders of magnitude higher than the former one, a jump similar to the one that separates it from the value deducted in this article and, in any case, very different from the Planck mass.

The discrepancies in the obtained results with currently accepted values, justify a deeper analysis which allows determining the correct replacement of the constant ε_0. An analysis that simultaneously compares the energies electric, gravitational and quantum of a real existent particle and that has a mass close to that pointed out by the Cosmos: the proton, allowing to deduce the true relationship between them in a real situation.

D-Quantum connection between electromagnetism and gravitation

To find equivalence between electromagnetic and gravitational fields, it is necessary to find a common element that serves as a comparison pattern. At the most elementary level, this element is provided by the Relativistic Uncertainty Principle (Berestetskij, V.B. et al., 1978), applied to a proton of mass m_p, at rest. The uncertainty $\Delta X_{p,0}$ in the temporal component of space-time is given by (Berestetskij, V.B. et al. – 1978):

$$\Delta X_{p,0} = \frac{\hbar}{m_p \cdot c} = 2{,}1 \cdot 10^{-16} \qquad \text{(D.1)}$$

The reason why a particle may have an uncertainty in its position when at rest is due to the fact that “rest” refers to the 3 spatial dimensions. Since the principle is relativistic, it is considering also the temporal dimension such that $\Delta X_{p,0} = c \cdot \Delta t$, where Δt is the time uncertainty in the measurement of its energy, which can be seen as a "margin" of movement in the temporal dimension.

Equivalences between the energies of a proton at rest

From (D.1) it is possible to obtain the relativistic energy of the proton at rest and using the formula of the constant α of the fine structure, it can be related to the electrical energy between two units of charge:

$$m_p \cdot c^2 \approx \frac{\hbar \cdot c}{\Delta X_{p,0}} = \frac{K \cdot e^2}{\alpha \cdot \Delta X_{p,0}} \qquad \text{(D.1.1)}$$

Since the proton should be pure energy, its radius r_p should be given by its electric self-energy and therefore be similar to:

$$r_p \sim \frac{k \cdot e^2}{m_p \cdot c^2} \sim 1{,}5 \cdot 10^{-18} m = \alpha \cdot \Delta X_{p,0} \qquad \text{(D.2)}$$

This leads to determine that the energy of the proton at rest is equivalent to its electric self-energy:

$$m_p \cdot c^2 \approx \frac{\hbar \cdot c}{\Delta X_{p,0}} = \frac{K \cdot e^2}{r_p} \qquad \text{(D.1.2)}$$

Since the charges are equal and one of them has the mass of the proton, the other must also have the same mass. Therefore, to obtain the gravitational energy equivalent to the relativistic-quantum one, it will be necessary to replace the constant $\hbar \cdot c$ by the combination $G \cdot m_p^2$ defining a new constant S_p:

$$S_p = \frac{\hbar \cdot c}{G \cdot m_p^2} = 1{,}69 \cdot 10^{38} \qquad \text{(D.3)}$$

This constant agrees with the basis used by Chandrasekhar-Wilson to determine the maximum masses of the cosmic bodies and therefore is not a conceptual invention, but a reality of the Cosmos (Pardi J.A. -2019).

Using this constant it can be described the relationship between all the energies involved:

$$m_p \cdot c^2 \approx \frac{\hbar \cdot c}{\Delta X_{p,0}} = \frac{K \cdot e^2}{r_p} = \frac{G \cdot S_p \cdot m_p^2}{\Delta X_{p,0}} \qquad \text{(D.4)}$$

To avoid confusion, it is convenient to separate the charge/mass of the proton from the different potentials (indicated in parentheses), which give rise to the speed:

$$m_p \cdot c^2 \approx \frac{\hbar \cdot c}{\Delta X_{p,0}} = \left(\frac{K \cdot e}{r_p}\right) \cdot e = \left(\frac{G \cdot S_p \cdot m_p}{\Delta X_{p,0}}\right) \cdot m_p \qquad \text{(D.4.1)}$$

Conceptual confirmation that G is not a good replacement for ε_0

This separation of functions is fundamental to understand the reason why it is wrong to use the constant G as a replacement of ε_0, a replacement done in the wrong assumption (conscious or subconscious) that the constant S_p is distributed among the masses m_p, since in the electric equation the charges are equal and in the gravitational one the masses seem to be too.

This consideration forgets that, although if apparently equal in magnitude, each charge has its own function and both are different. In effect, one of the charges generates the field that acts on the other. Therefore, instead of seeing two charges, one should see a charge and a potential acting on it.

To understand it better we must think about the physical fact represented by the relativistic equation. The uncertainty in the denominator indicates that the energy derives from the interaction of a potential with a charge or a mass; in the gravitational case the mass of the proton. Therefore, the intensity of the gravitational potential

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does not depend on the mass with which it interacts, but on the mass that generates it.

What the (D.4.1) says is that to generate that field, a gravitational potential of magnitude $G \cdot M_{Qm}/\Delta X_{p,0}$ is needed with $M_{Qm} = S_p \cdot m_p$.

This explains why it is wrong to distribute S_p among the masses, converting them into the Planck mass.

Final version of the energy equations of the proton at rest

According to this reasoning, M_{Qm} is the minimum possible mass to this relativistic uncertainty since a lower mass multiplied by the universal gravitation constant, will never be equal to the constant $\hbar \cdot c$ present in the numerator of the equation describing a quantum energy.

Since c is the highest escape velocity, the relationship $M_{Qm} / \Delta X_{p,0}$ corresponds to that of a black hole and therefore $\Delta X_{p,0}$ has the order of magnitude of Schwarzschild radius r_{sch}:

$$r_{sch} \approx \frac{G \cdot S_p \cdot m_p}{c^2} = \frac{G \cdot M_{Qm}}{c^2} = \Delta X_{p,0} \quad \text{(D.5)}$$

Taking into account this important difference of functionalities and the equivalence of values between $\Delta X_{p,0}$, r_{pm} y r_{sch}, it is now possible to establish the equality sought between the four energies (relativistic, quantum, electric and gravitational) replacing $\Delta X_{p,0}$ in the denominators of electric and gravitational energy by the corresponding parameter (r_p or r_{sch}):

$$E_{p,0} = m_p \cdot c^2 = \frac{\hbar \cdot c}{\Delta X_{p,0}} \approx \frac{K \cdot e^2}{r_p} \approx \frac{G \cdot M_{Qm} \cdot m_p}{r_{sch}} \quad \text{(D.4.2)}$$

The fields energies equations

From these expressions is also possible relating the self-electric energy with the energy stored in the space surrounding the charge:

$$\frac{\hbar \cdot c}{\Delta X_{p,0}} \approx \frac{\varepsilon_0}{2} \cdot \int_{r_p}^{\infty} E^2 \cdot (4\pi \cdot r^2) \cdot dr \approx \varepsilon_0 \cdot E_p^2 \cdot V_p \approx \frac{K \cdot e^2}{r_p} \quad \text{(D.6)}$$

Where $E = Ke/r^2$, $E_p = Ke/r_p^2$ y $V_p = 4\pi \cdot r_p^3/3$

In the same way it can be calculated the energy of the space surrounding the mass M_{Qm} generating the field, using the same calculation procedure but changing the constants and the field expression:

$$\frac{\hbar \cdot c}{\Delta X_{p,0}} \approx \frac{1}{GS_p} \int_{r_{sch}}^{\infty} g^2 \cdot (4\pi \cdot r^2) \cdot dr \approx \frac{1}{GS_p} \cdot g_{\Delta X_{p,0}}^2 \cdot r_{sch}^3 \approx \frac{G \cdot M_{Qm} \cdot m_p}{r_{sch}} \quad \text{(D.6.1)}$$

Where $g = \frac{G \cdot M_{Qm}}{r^2}$ and $g_{\Delta X_{p,0}} = \frac{G \cdot M_{Qm}}{r_{sch}^2}$

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In summary, the energies of the internal electric and gravitational fields of a proton at rest have the same order of magnitude of its relativistic energy:

$$\frac{\hbar \cdot c}{\Delta X_{p,0}} \approx \varepsilon_0 \cdot E_p^2 \cdot V_p \approx \frac{1}{GS_p} \cdot g^2_{\Delta X_{p,0}} \cdot r^3_{sch} \qquad \text{(D.6.2)}$$

Although if the computing of the gravitational energy and the black hole field are very simplified, being able to produce a certain skepticism about the validity of the gravitational equations and their variables, the confrontation with the Cosmos must be who decides it. Meanwhile, the new constant GS_p will allow advancing in the justification of the discretizations found by Agnese and Festa.

The relativistic energy variation

The equivalence between the energies of (D.4.2) is maintained even when the proton gets motion due to the interaction with a graviton acquiring a relativistic energy variation $\Delta E = m_p \cdot v \cdot c$ producing only an adjustment in the denominator of the field due to the change in the uncertainty in the position of m_p:

$$E_{p,v} = m_p \cdot v \cdot c = \frac{\hbar \cdot c}{\Delta X_{p,v}} \approx \frac{K \cdot e^2}{a_{p,v}} \approx \frac{G \cdot S_p \cdot m_p^2}{a_{sch,v}} = \frac{G \cdot M_{min} \cdot m_p}{a_{sch,v}} \qquad \text{(D.7)}$$

Where $a_{p,v} = (c \cdot r_p / v)$ and $a_{sch,v} = (c \cdot r_{sch} / v)$

This case definitely confirms the independence between the field and the mass and, therefore, that the constant S_p affects only the mass generating the quantum field by setting its minimum limit in $S_p \cdot m_p$.

In practice, it can be said that the limit found by Rosenfeld for the mass of the test body, has now passed to the generating mass of the field, with a greater intensity.

The former reasoning sets the basis to applying the Quantum Field Theory to gravitational fields.

Writing conventions

In addition, to simplify the writing of the equations, from now on, the following replacements will be used: $GS_p = G \cdot S_p$, $\hbar c = \hbar \cdot c$ and $4\pi = 4 \cdot \pi$ and to simplify the references to the "quantum of gravitational radiation" it will be called directly "graviton", although in this article it is attributed a very different value to the currently accepted, as already mentioned.

The Ampere-Maxwell law in the gravitational domain

The Ampere-Maxwell law is fundamental in interactions where photons are absorbed by particles of their same dimension and therefore is an important part in the theory of errors in the measurement of field components of Bohr and Rosenfeld. Therefore it is essential to verify if it is still applicable with the gravitational fields and under what conditions.

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In the gravitational domain, the law can be deduced from the density of the impulse p/V transmitted to the particle of volume $V \sim L^3$ and density ρ, by a photon of the same dimension:

$$\frac{4\pi}{3} \cdot \frac{p_x}{V} = \frac{4\pi}{3} \cdot \rho \cdot v_x \approx \frac{\hbar}{\Delta X \cdot L^3} = \frac{\sqrt{\hbar c}}{L^2} \cdot \frac{\sqrt{\hbar c}}{\Delta X \cdot L \cdot c} \qquad \text{(D.8)}$$

To transform the first quotient of the last term in a field, it is necessary to add the new constant GS_p to the numerators:

$$\frac{4\pi}{3} \cdot GS_p \cdot \rho \cdot v_x \approx \frac{\sqrt{GS_p \cdot \hbar c}}{L^2} \cdot \frac{\sqrt{GS_p \cdot \hbar c}}{\Delta X \cdot L \cdot c} = \delta \bar{F}_x \cdot \frac{\hbar}{\Delta X \cdot L \cdot m_p} = \delta \bar{F}_x \cdot \frac{v_x}{\Delta X} \approx \frac{\delta \bar{F}_x}{\Delta t} \qquad \text{(D.9)}$$

The interval Δt is the one corresponding to the oscillation time of the field δF_x.

This is the equivalent of the Ampere-Maxwell Law but in the gravity domain. From this law can be deduced the average intensity of the oscillating field component δF_x:

$$\delta \bar{F}_x \approx \frac{\sqrt{GS_p \cdot \hbar c}}{L^2} \approx \frac{4\pi}{3} \cdot GS_p \cdot \rho \cdot (v_x \cdot \Delta t) = \frac{4\pi}{3} \cdot GS_p \cdot \rho \cdot \Delta X \qquad \text{(D.10)}$$

The constant of this law is 1/3 inferior to the electromagnetic version and is valid for masses of any magnitude and dimension.

From (D.10) it is possible to deduce Δt and the relation between ΔX and L:

$$\Delta X \approx \sqrt{\frac{\hbar c}{GS_p}} \cdot \frac{L}{m} = \frac{L}{N_p} \quad \Longrightarrow \quad \Delta t = \frac{L}{v_x \cdot N_p} \qquad \text{(D.11)}$$

Where N_p is the amount of proton masses (or neutral H atoms, given the similarity between both masses) contained in m.

In the case that the magnitude of the mass is equal to the unit mass (m=m_p) and the dimension of the graviton equal to that of a proton, one might think that the field of the interaction would coincide with the field of the free graviton, since ΔX=L. However, this will not be the case because the oscillation time is different (L/v_x instead of L/c).

This happens because the presence of a "real" mass introduces an uncertainty in the determination of the time of the interaction, something that does not happen with the unit mass since it does not exist, it is a "phantom mass", only a reference. The consequences of the presence of a real mass will be seen in the analysis of interactions at very low speeds ($v \ll c$).

As seen in paragraph D, an interaction of a proton with a graviton of radius similar to the Schwarzschild one results in only one movement in the temporal dimension, transforming the previous reasoning into a "mental experiment". However, a neutral H

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atom has a mass similar to the proton, but a much larger size, transforming the "mental experiment" into possible and therefore valid conclusions.

The validity in the real Universe, of the interaction between a neutral H atom and a graviton of its same volume, is a further confirmation for the new constant GS_p of the field energy.

The "pilot" wave

The field δF_x can be interpreted as the one that pilot the body movement. Since Einstein noticed that the energy acquired by a mass does not transform into a mass but adds to its energy at rest, it is possible to think that this field is the result of this additional energy which would give coherence to the integration of the quantum field to the relativistic one and would demonstrate the existence of the weak gravitational radiation proposed by Rosenfeld.

A similar proposal was made by the physicist David Bohm in 1952 about hidden variables of quantum physics where a de Broglie wave would guide the body movement. This theory, known as "De Broglie-Bohm" would explain the dual wave-particle behavior produced by the double-slit experiment.

It is possible that a more extensive study of Ampere-Maxwell's law in the gravitational domain may lead to a similar conclusion.

Extension of the writing conventions

From (D.10) it appears the need to add the constant [4π/3] to GS_p. Replacing this new value in the constant of the gravitational field energy in (D.6.1) and (D.6.2) and adding the same constant to r_{sch}^3 it will be obtained a more accurate value for the volume and energy. Therefore it is convenient to replace ε_0 with a new constant $\varepsilon_g = 3/(4\pi \cdot GS_p)$. However, within the scope of this project, it will be useful to remember "its composition" and therefore the full denomination $1/[4\pi GS_p/3]$ will be used.

Confirming m_p as the unit of mass

Replacing G by the new constant in the gravitational field's energy equation defined in (B.3):

$$\delta E_g = \frac{\hbar \cdot c}{L} \approx \varepsilon_g \cdot \delta \bar{g}^2 \cdot V \approx \frac{1}{(4\pi GS_p/3)} \cdot \left(\frac{\sqrt{GS_p \cdot \hbar c}}{L^2}\right)^2 \cdot (4\pi \cdot L^3/3) \qquad \text{(D.12)}$$

Applying the procedure used for (B.3), $\mathrm{m_p} \approx \sqrt{\hbar c/\mathrm{GS_p}}$ is confirmed as the unit mass:

$$\delta E_g = \frac{\hbar c}{L} \approx \sqrt{\left(\frac{\hbar c}{L}\right) \cdot \left(\frac{1}{(4\pi GS_p/3)} \cdot \delta \bar{g}_X^2 \cdot V^3\right)} = \sqrt{\frac{\hbar c}{GS_p}} \cdot \delta \bar{g}_X \cdot L = m_p \cdot \delta \bar{g}_X \cdot L \qquad \text{(D.13)}$$

The physical meaning of the unit mass

The procedure to obtain the unit mass m_p in (D.13) is purely mathematical and doesn't indicate the physical reason for the existence of a mass that, in reality, does not appear in the field energy equation and, therefore, could be considered a "ghost mass".

The determination of the same as "mass limit" using Rosenfeld's reasoning gives it a physical sense, but it does not connect it directly with the energy of the field but with the impulse that it transmits, therefore, it is a physical sense external to the field.

To understand the correct meaning as an implicit component of the energy of the field during the interaction, it must be started from the uncertainty of the internal potential of the mass (Treder H-J. – 1979). From (D.12):

$$\Delta\varphi_i \approx \Delta\bar{g} \cdot L \approx \frac{GS_p}{L} \cdot \frac{\hbar}{\left(\sqrt{GS_p \cdot \hbar c/L^2}\right) \cdot L \cdot (L/c)} \approx \frac{GS_p \cdot \Delta m}{L} \qquad \text{(D.14)}$$

According to Bohr demonstrated to Einstein (Sixth Congress of Solvay, 1930 and Rosenfeld L.- 1965), the second term defines the uncertainty in the determination of a mass subjected to the action of a field $\Delta\bar{g}$, along the time (L/c), with an uncertainty in the magnitude $L \approx \Delta X$ (Treder H-J.-1979):

$$\Delta m \approx \frac{\hbar}{\Delta\bar{g} \cdot L \cdot (L/c)} \approx \frac{\hbar}{\left([4\pi GS_p/3] \cdot \rho \cdot \Delta X\right) \cdot L \cdot (L/c)} = m_p \qquad \text{(D.15)}$$

From the coincidence between the magnitude obtained in (D.13) with that obtained in (D.15) it can be concluded that *the mass implicit in the equation of the energy of the field, is in fact an uncertainty in the determination of the mass driven by the field, whatever its magnitude. A true "ghost mass", as already said, that, at ultra-relativistic speeds, coincides with the mass of the proton*. But, what happens at non-relativistic speeds?

E- Characteristics of the interaction graviton-particle when $v \ll c$

Given that all the cosmic objects that are objectives of this research have non ultra-relativistic speeds, it is convenient to analyze what other consequences can have the lower speeds in the field equations.

In the case of an interaction of the graviton described by (D.12) with a mass of equal volume, it must be taken into account that the interaction interval will have an uncertainty which, in turn, will produce an uncertainty in the determination of the associated energy. The magnitude of the uncertainty in the determination of time is given by $\Delta t \approx (c/v) \cdot (L/c) = L/v$ coinciding with the oscillation time of the field product of the interaction. The uncertainty in the energy of the interaction is given by replacing this uncertainty in (D.12):

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$$\Delta E_{i,v} \approx \frac{\hbar v}{L} \approx \frac{1}{[4\pi G S_p/3]} \cdot \left(\frac{\sqrt{GS_p \cdot \hbar v}}{L^2}\right)^2 \cdot (4\pi \cdot L^3/3) \qquad \text{(E.1)}$$

Applying the procedure used for (B.3), it is obtained a different magnitude for the unit mass:

$$\delta E_g = \frac{\hbar v}{L} \approx \sqrt{\left(\frac{\hbar v}{L}\right) \cdot \left(\frac{1}{(4\pi G S_p/3)} \cdot \delta \bar{g}_X^2 \cdot V^3\right)} = \left(m_p \cdot \sqrt{\frac{v}{c}}\right) \cdot \delta \bar{g}_X \cdot L \qquad \text{(E.2)}$$

This mass is confirmed by the mental experiment of Einstein-Bohr explained before. De (E.1):

$$\Delta m \approx \frac{\hbar}{\left(\sqrt{GS_p \cdot \hbar v}/L^2\right) \cdot L \cdot (L/v)} = m_p \cdot \sqrt{\frac{v}{c}} \qquad \text{(E.3)}$$

This explains why the value obtained in (C.3) for the unit mass, using the dimension of the "hypothetical weak gravitational radiation quantum", was not equal to the mass of the proton; but to the uncertainty in the determination of the same. ***The difference did not have relevance at that time, given that the objective was only to find the order of magnitude of it but this coincidence between the hypothesis and the reality of the Solar System has an immense importance when confirming the validity of the answer that Bohr gave to Einstein.***

*Since the unit of mass changes its magnitude at low speeds**, in quantized gravitational fields, it should be considered only a "reference mass"***.

A new graviton product of the interaction

As seen in the new Ampere-Maxwell gravitational law, the graviton-particle interaction produces a new field with an oscillation time and a unitary mass different from the original graviton.

In addition, given that it is the field of an interaction, it will be important to preserve equality (D.10), even for the new unit mass. Although if Δm is less than the mass of a proton but much larger than that of an electron, it is abnormal in the Cosmos and therefore could only be found as a portion of a larger mass. The former analysis of the Solar System in the determination of the unitary mass without using G has shown that this possibility is not theoretical but real.

In this particular case and as seen in (C.3), Δm can be determined using the density of the body. Using the subscript v to identify the variables affected by the low speed:

$$\Delta m = \rho \cdot (4\pi/3) \cdot L_v^3 \qquad \text{(E.4)}$$

It is evident that when $\Delta m < m_p$, L_v must be lower than L to preserve density:

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$$L_v = \sqrt[3]{\frac{\Delta m}{m_p}} \cdot L = \sqrt[6]{\frac{v}{c}} \cdot L \tag{E.4.1}$$

So, for the same density, at low speeds the graviton dimension will be smaller. Therefore the value of L obtained in (C.2) was actually the value of L_v since $(\alpha \cdot c) \ll c$. To determine the value L of the "original" graviton, it can be used (E.4.1), obtaining a value closer to Bohr's radius (a_0=5,3·10^{-11}) than that obtained in (C.2):

$$L = \sqrt[6]{\frac{c}{v}} \cdot L_v = \sqrt[6]{\frac{1}{\alpha}} \cdot 1{,}6 \cdot 10^{-11} = 5{,}6 \cdot 10^{-11} \approx a_0 \tag{E.4.2}$$

Equations of the new graviton

All these differences define new parameters for the graviton of the interaction and, as a consequence, new equations for its definition, beginning with the energy of the same defined from (E.1) and extended with the law of Ampere-Maxwell in the gravitational domain:

$$\Delta E_{i,v} \approx \frac{\hbar v}{L_v} \approx \frac{1}{[4\pi G S_p/3]} \cdot \left(\frac{\sqrt{GS_p \cdot \hbar v}}{L_v^2}\right)^2 \cdot (4\pi \cdot L_v^3/3) = \frac{1}{[4\pi G S_p/3]} \cdot \left([4\pi G S_p/3] \cdot \rho \cdot \Delta X_v\right)^2 \cdot V_v \tag{E.1.1}$$

As a result, the uncertainty in the position of the mass will be slightly different from that obtained in (D.11):

$$\Delta X_v \approx \sqrt{\frac{GS_p \cdot \hbar v}{L_v^4}} \cdot \frac{1}{GS_p \cdot \rho} = \Delta m \cdot \frac{L_v}{m} = \frac{L_v}{N_\Delta} \tag{E.5}$$

As it can be seen, the dimension of the graviton product of the interaction will continue to be equal to ΔX_v when m=Δm, but the uncertainty in the position of the mass will decrease with the increasing of the amount of reference masses Δm contained in it, just as in electromagnetism where the uncertainty decreases with the amount of elementary charges contained in the test body. This variation happens also at ultra-relative speeds.

The impulse transmitted by the graviton to the test body is given by:

$$\Delta p_{i,v} = m \cdot v \approx \frac{\hbar}{\Delta X_v} \approx m \cdot \left([4\pi G S_p/3] \cdot \rho \cdot \Delta X_v\right) \cdot \frac{L_v}{v} \tag{E.6}$$

Where it is possible to check that the value of ΔX_v obtained from the impulse coincides with that of the field given in (E.5).

The velocity transmitted to the body by the graviton field during the uncertainty in the time of the interaction and the interaction time itself can be deduced replacing in (E.6) the expression of ΔX_v given in (E.5):

$$v \approx \left(\frac{\sqrt{GS_p \cdot \hbar v}}{L_v^2}\right) \cdot \frac{L_v}{\bar{v}} \approx \sqrt{\frac{GS_p \cdot \Delta m}{L_v}} \quad \Rightarrow \quad \Delta t \approx \frac{L_v}{v} = \sqrt{\frac{L_v^3}{GS_p \cdot \Delta m}} \tag{E.7}$$

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From these equations and from (E.6) it is possible to deduce L_v with only the density:

$$L_v \approx \frac{\hbar}{\Delta m \cdot v} \approx \frac{3 \cdot \hbar \cdot \Delta t}{\rho \cdot 4\pi \cdot L_v^4} = \frac{\hbar}{L_v^4 \cdot \sqrt{GS_p \cdot (4\pi \cdot \rho/3)^3}} \implies L_v \approx \left(\frac{\hbar}{(4\pi \cdot \rho/3)^{3/2} \cdot \sqrt{GS_p}}\right)^{1/5} \quad \text{(E.7.1)}$$

The interaction of the new field with a neutral H atom of mass m_H will produce an uncertainty ΔX lower than the dimension L_v of the graviton containing it, fulfilling the Bohr and Rosenfeld condition for a valid measurement ($\Delta X \leq L$). From (E.5):

$$\Delta X \approx \Delta m \cdot \frac{L_v}{m_H} = \sqrt{\frac{v}{c}} \cdot L_v < L_v \quad \text{(E.8)}$$

The (E.1) and the equations of this paragraph complete the model proposed by Leon Rosenfeld for a weak gravitational radiation.

F- Verifying the results in the Cosmos

Other research obtained similar results based on totally different considerations and analyzes.

The Treder's New Uncertainty Principles

In his 1979 conference, for the centenary of the birth of Albert Einstein, Hans-Jürgen Treder presents a proposal to unify the General Theory of Relativity with Quantum Mechanics through the uncertainty in the determination of the components of the gravitational field (Treder, H-J. – 1979).

Using the theory of the errors of measurement of electromagnetic fields, developed in 1933 by Niels Bohr and Leon Rosenfeld, it obtains two New Uncertainty Principles that affect not only the intensity of the field Γ but also the metric $g_{i,k}$ of space-time:

$$\Delta\Gamma \geq \frac{G \cdot \hbar}{(c \cdot \Delta X)^3} \approx \frac{l_{pl}^2}{\Delta X^3} \quad y \quad \Delta g_{i,k} \approx \frac{\Delta\varphi}{c^2} \geq \frac{2 \cdot G \cdot \hbar}{c^3 \cdot L^2} \approx 2 \cdot \left(\frac{l_{pl}}{L}\right)^2 \quad \text{(F.1)}$$

With this application of the Bohr-Rosenfeld theory, Treder is implicitly assuming that a planet or a natural satellite orbiting around a central mass, meet the same conditions as a test body used to measure the field.

Although if at the beginning of its development Treder indicates ΔL as the dimension of the test body, at the end ΔL ends up being equal to ΔX without explanation. This change would indicate that ΔL has "evolved" along the theoretical development until acquiring the dimension of a graviton, just when $\Delta X \approx \Delta L$. This outcome is compatible with the assumption developed at the beginning of this study about the fractionation of the classical field in quantum oscillators.

For non-ultra-relativistic speeds, the terms on the right of equality, in both equations, must be multiplied by (c/v) as indicated by the same Treder.

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The outcomes of this development are congruent with a theory developed 43 years earlier, by the Russian physicist Matvey Petrovich Bronstein, using the same conclusions of the Bohr and Rosenfeld study (Gorelik G. - 1992), but connecting them directly with the equations of the General Theory of Relativity. His conclusions reinforce the connection between the General Theory of Relativity and Quantum Mechanics, through the uncertainty in the field measurement and in the space-time metric, proposed by Treder.

Since the conclusions of Treder and Bronstein are obtained from the incorrect replacement of ε_0, it is necessary to apply the correction of the GS_p constant to both to apply them to the Cosmos.

Congruence of the Treder results with the graviton

To test the congruence of the graviton defined here, with the results published by Treder in the aforementioned document, it is sufficient to use the first of the (F.1) to determine the speed transmitted by the field, replacing G with GS_p.

This replacement clearly emerges from Treder's reasoning to obtain the expression of $\Delta\Phi\cdot(\Delta L)^2$ from the Einstein Equivalence Principle, if (D.4.1) is used for the replacement of KQ by $GS_p\cdot m_p$ in the electromagnetic equation $\Delta\Phi\cdot(\Delta L)^2 = KQ\cdot\hbar/(m_p\cdot c)$ resulting from the uncertainty in the determination of the field component (Treder H-J-1979):

$$\Delta\Phi\cdot(\Delta L)^2 = \frac{K\cdot Q\cdot\hbar}{m_p\cdot c} \equiv \frac{GS_p\cdot\hbar}{c} \quad\Longrightarrow\quad \frac{\Delta\Phi}{c^2} = \frac{GS_p\cdot\hbar}{c^3} \approx \Delta\Gamma\cdot \mathrm{L_v} \tag{F.2}$$

The experiment of Eötvös erroneously led Treder to consider the equality between the gravitational and inertial masses as the components of the gravity energy equation, ignoring the functional differences between them. It was actually the gravitational field of the Earth that Eötvös used to determine the gravitational mass in his experiment and not the other mass in the torsion balance.

In any case, this problem was hidden by the use of an inequality between the relativistic energy and the gravity energy, leaving an undefined difference between both. This lack of definition detracts from its usefulness. The reasoning developed from the Relativistic Uncertainty Principle applied to a proton at rest, is able to overcome this issue.

Since the Treder principle is applied in a low velocity environment, such as in the Solar System, the correction c/v must also be added to (F.1) and replaces ΔX by L_v, since Treder equals this last variable with the uncertainty in the position of the test body:

$$\frac{v^2}{c^2} = \Delta\Gamma\cdot \mathrm{L_v} \geq \frac{GS_p\cdot\hbar c}{c^2\cdot(c\cdot L_v)^2}\cdot\frac{c}{v} \approx \frac{1}{c^2}\cdot\left(\frac{\hbar}{m_p\cdot L_v}\cdot\sqrt{\frac{c}{v}}\right)^2 \approx \frac{1}{c^2}\cdot\left(\frac{\hbar}{\Delta m\cdot L_v}\right)^2 \tag{F.2.1}$$

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Clearing v in (F.2.1), it is obtained a result congruent with (E.6) replacing m with Δm and remembering that in this case $\Delta X_v \sim L_v$:

$$v \approx \frac{\hbar}{\Delta m \cdot L_v} \tag{F.3}$$

Computation of α_g in the Solar System

Given that, like Bohr and Rosenfeld, Treder ignores the number n of quanta present in the field, because it does not affect the accuracy of its component measurement, it is therefore logical to assume that the results obtained from its New Principles of Uncertainty correspond to $n = 1$.

Then, it is possible to take advantage of the relationship between L_v and ρ shown in (E.7.1) to try to obtain the value of α_g.

Replacing v/c with α_g and L_v by (E.7.1) in the first and third term of (F.2.1) and ordering terms results in the following expression:

$$\alpha_g \approx \left({S_p}^{6/5} \cdot {l_{pl}}^2 \cdot \sqrt[5]{\frac{G}{\hbar^2}} \right)^{1/3} \cdot \left(\frac{4\pi \cdot \rho}{3} \right)^{1/5} \tag{F.4}$$

This shows that, according to the theory of gravitational radiation applied to the theory of measurement errors of the components of electromagnetic fields in the gravitational domain, α_g is not constant but depends on the density of the test body.

Its value for the average density of the Solar System bodies considered in this study ($3 \cdot 10^3$ Kg/m^3) is $\alpha_g = 5{,}9 \cdot 10^{-4}$, higher than that published by Agnese and Festa in the aforementioned study of 1998 ($\alpha_g \approx 4{,}8 \cdot 10^{-4}$).

The minimum impact of the density in the determination of α_g (1/5 of its value) is the one that surely allowed obtaining an almost constant value. In fact, the magnitude determined by Agnese and Festa must represent the average value of the densities of the Cosmos, surely lower than that of the Solar System containing rocky bodies of high densities.

One way to test this hypothesis is to replace the mathematical average by the weighted one that for the stars of the Solar System considered in this study is $1{,}141 \cdot 10^3$ Kg / m3, which gives the weighted average value of $\alpha_g = 4{,}841 \cdot 10^{-4}$, close to the upper limit of the variation estimated by Agnese and Festa ($\alpha_{g\text{-máximo}} = 4{,}826 \cdot 10^{-4}$).

Probably this is the first time that an explanation of α_g is obtained from reasoning based, purely and exclusively, on existent physical principles, *since its discoverers obtained it statistically from the average speed of the planet Mercury in its orbit. All subsequent works of other researchers were based on this value, not explaining its origin without introducing new physical models not yet tested.*

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Besides this, the result has the double value of confirming, based on the data of the Cosmos, the validity of the new constant GS_p and the New Principles of Uncertainty of Treder fixed by using this new constant.

Consequences of the Treder's New Uncertainty Principles

The uncertainty in the determination of the gravitational potential $\Delta\Phi$, which defines the dimension of the minimum orbits of the self-gravitating systems of the Cosmos, could be the origin of the discretization of the geometry of the Universe, also known as "quantum foam structure-geometric" of space-time (Treder HJ, 1979). The Fine Structure of the Cosmos (Pardi J.A.-2019) would be the manifestation of it.

The introduction of the quantum number n could explain the discretization of the orbits of the self-gravitating systems, completing the description of this fine structure

The Wilson's limit on the gravitational potential of cosmic bodies

Although the existence of a limit in the potential of the orbits of the Cosmos may seem surprising, the astronomer Albert G. Wilson (Wilson, A.G., Edelen D.G.B.-1968) also found a limit for the gravitational potential of the cosmic bodies (stars, galaxies and galaxy clusters) given by (Pardi J.A.-2019):

$$V_{min} = -\left(\frac{G\cdot M}{r}\right)_{MAX} \approx -10^{13} \approx -\frac{GS_p\cdot m_p}{a_0} \qquad \text{(F.5)}$$

This expression of the mass minimum potential makes clear that ***the GS_p constant is already present in the "real" Cosmos what can be considered a further proof of the validity of the GS_p constant, since it has gone from theory to reality.***

The structure of the cosmic masses of Chandrasekhar-Wilson

In 1937 the Nobel Prize Subramanyan Chandrasekhar found a relation between fundamentals constants that give the maximum values for the masses of stars, galaxies and the same Universe (Chandrasekhar S. - 1937). Later the astronomer Albert G. Wilson simplified and extended it to planets, star clusters and galaxy clusters (Pardi J.A. -2019). Chandrasekhar's formula and Wilson's subsequent simplification were as follows:

$$M_{MAX}^{v} \approx \left(\frac{hc}{G}\right)^{v} \cdot \frac{1}{{m_p}^{2v-1}} \Longrightarrow S_p^{v} \cdot m_p \quad con\ v = \frac{11}{8}; \frac{12}{8}; \frac{13}{8}; \frac{14}{8}; 2 \qquad \text{(F.6)}$$

The exponents were the same in both formulas for stars, galaxies and the Universe.

The base mass of the Wilson formula ($S_p\cdot m_p$) to compute the maximum masses coincides totally with the minimum mass M_{Qm} necessary to generate a quantum gravitational field according to (D.5) and the order of magnitude of the minimum mass of the Wilson's cosmic structure ($\alpha_g\cdot S_p\cdot m_p$)$^{11/8}$ also coincides with M_{Qm}.

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These coincidences, in addition to proving the validity of M_{Qm}, also shows that the Universe contains masses capable of generating quantum gravitational fields in its main structures.

The Faizal's, Khalil's and Das' Time Crystals

A study published in 2016, based on a modification to Heisenberg's algebra and applied to atomic systems, suggests that time behaves like a crystal, that is, time can be seen as a discrete emission that arises in space and not as a wave keep going (Mir Faizal et al.-2016).

According to these authors, the size of the crystals resulting from the rhythm of spontaneous emission of hydrogen atoms, would be of the order of 10^{-17}s, a magnitude much greater than the Planck time but similar to the uncertainty in the measurement of the interaction time between a graviton of dimension equal to that of the H atom with which come into collision:

$$t \approx \frac{\hbar}{m_H \cdot (\alpha_g \cdot c)^2} \approx 10^{-17} \qquad \text{(F.7)}$$

According to the authors, in the same year, these crystals were observed in Floquet systems that are not in equilibrium and in disordered dipolar systems.

This coincidence reinforces the result obtained in this study introducing the constant S_p in its New Uncertainty Principles.

Because of the characteristics thereof, the time uncertainty of the graviton-H atom interaction can be considered a time crystal since it is the fourth dimension of the interaction used by Bohr and Rosenfeld to mediate the field components and it is also discontinuous, since it transmits the impulse to the body in orbit in a discrete way.

These studies (that of Treder and this of the time crystals), have a common antecedent in physicist Bruce DeWitt since he also found the uncertainty in the relativistic metric g_{ik} (Treder HJ.- 1979) and the time crystals were predicted using a deformed version of the Wheeler-DeWitt equation (Mir Faizal et al.-2016).

G-Conclusion

It has been proven that the proton and the neutral H atom at its fundamental level have turned out to be the basic components from which to develop a more complete quantum field theory of gravity that encompasses masses of larger magnitudes and dimensions in later investigations.

The mass of the proton has turned out to be a valid "reference mass" to replace the electric charge unit, although unlike this, which is a relativistic invariant, the reference mass depends on the speed transmitted by the graviton.

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In spite of this, it has been possible to demonstrate with reasonable certainty through the comparison with the Cosmos reality, that the combination of the constants G and S_p, necessary to compute the graviton energy, is present in the Cosmos structure, although if G continues to be valid to determine the intensity of a classical Newtonian field.

The new constant puts a lower limit ($S_p \cdot m_p$) for a mass to be able to generate a quantum gravity field, leaving out masses below this limit. This restriction does not seem to be limiting in the Cosmos, where most of the masses of its main structures are higher than this value.

The conditions of an interaction between a field and a mass seems to reveal that quantum gravitational fields are composed of oscillators that push fractions of the cosmic bodies mass, following the quantum rules of electromagnetic fields. The dimensions of these oscillators are similar to the neutral, non excited, H atom. That would explain the discretizations observed in the Cosmos.

The most striking result of the replacement of the constant G by GS_p in the Treder's New Uncertainty Principle, was that it allowed explaining, for the first time, the origin of the constant α_g found by Agnese and Festa based in well known physical theories. However, it has been shown that α_g is not a true constant but it depends on the density of the body in orbit. The value found by Agnese and Festa is only a universal average value.

If the development of a complete theory based on these fundamentals and subsequent verifications confirms that the discretizations found in the Cosmos are due to the uncertainty in the relativistic metric g_{ik}, as proposed by Treder, it will have confirmed his proposal to unify the General Theory of Relativity with the Quantum Theory, avoiding the need to reconcile the logical and mathematical formalisms of both, which are so dissimilar (Treder HJ.-1979). A good beginning for this development could be the work of Bronstein before mentioned.

Meanwhile it is possible to continue the development of this research to try to explain the fine structure of the Cosmos by analyzing the structure of self-gravitating systems using the bases established in this research and the Solar System for verifications.

Addendum

A.1- Units of measures system used in this study

International System of Units, derived from the MKS System.

A.2 - List of the celestial bodies of the Solar System considered in this study

Planets (9): Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto.

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Natural satellites (36): Moon, Phobos, Deimos, Métis, Adrastea, Amalthea, Thebe, Io, Europe, Ganymede, Callisto, Leda, Himalia, Lysithea, Elara, Ananke, Carme, Pasiphae, Sinope, Mimas, Enceladus, Tethys, Dione, Rhea, Titán, Hyperión, Iapetus, Phoebe, Miranda, Ariel, Umbriel, Titania, Oberon, Triton, Nereid, Charon.

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