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Universe Discrete Granular Reality

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ABSTRACT

Is reality continuous or discrete ? As for the matter and the energy , both are composed of concrete elements : photons , electrons , molecules…Therefore it is pertinent to ask whether spacetime is made of any type of discrete , elementary ingredients . A preliminary approach to this issue is presented . It consists of numerical and geometric equivalences. The introduction of few parameters will help us to analyze some physical and cosmological subjects.

Introduction

It is known that any measurement under Planck's length do not have physical meaning . Theories that declare discreteness of the reality must consider such value as the minimum of spatial length . Energy only exists as indivisible units , quanta . As for spacetime there are two theories: reality is continuous or reality is a grid ,i.e. spacetime is made of discrete matters. Inspired by the second view will explore briefly some physical subjects .The assumption that exists some form of lattice of structure allow us to introduce in the matter several parameters of *granularity*.

Method

To develop the hypothesis of a discrete spacetime , will apply a couple of calculation tools .The way always be the same . We have picked several topics concerning the physical and cosmological scopes . Then will introduce in the equations the tools cited above .

Since we assumed that reality isn't continuous but made of discrete matters , will define the minimum item of such grid and then will write the amount of items involved in each of the physical systems to be analyzed .

The scale of the minimum item has been taken from theoretical physics . It correspond to the Planck's scale . Will typify such parameter as

$$(o) = \frac{1}{10^{35}}$$

The second parameter is defined below

$$(N_{...}) = a\ b\ c\ d \qquad (1)$$

a represents the proton frequency , obtained from the formula

$$a = \frac{p_m c^2}{h} = 2.26873\ x\ 10^{23}\ \frac{1}{s} \qquad (2)$$

p_m refers to proton mass , c is the speed of light in vacuum and h the Planck constant .All these values are described and properly referenced in the appendix at the end of the article.

b is a dimensionless variable , made of a particular series whose appearance shows a pattern that repeats at different scales

$$b = S_{...} + \frac{S_{...}}{10} + \frac{S_{...}}{10^2} + \frac{S_{...}}{10^3} + \cdots \qquad (3)$$

where

$$S_{...} = \left(\frac{1}{2} + \frac{1}{4} + \frac{1}{32} + \frac{1}{64}\right) \qquad (4)$$

Consequently $b = 0.885417$ (curious coincidence with significant digits of electric constant ε_0) Strictly speaking , we can say that such parameter perform the idea of discreteness par excellance.

Parameter c refers to the speed of light in vacuum (appendix) As for the last value d , has been introduced in order to a correct cancellation of the physical units.

$$d = 1\ \frac{s^2}{m} \qquad (5)$$

Write a dimensional analysis of the equation (1)

$$[a][c][d] = [T^{-1}]\,[LT^{-1}]\,[L^{-1}T^2] \qquad (6)$$

Therefore $(N_{...})$ is a dimensionless number whose value is

$$(N_{...}) = 6.02214\ x\ 10^{30} \qquad (7)$$

if we divide the parameter b by 10^7 will obtain a value identical to Avogadro's number

$$(N_{...}) = 6.02214\ x\ 10^{23} \qquad (8)$$

By the way , when multiply the orders of magnitude of $(N_{...})$ by the orders of magnitude of (o) we obtain

$$10^{23}\ x\ 10^{-35} = 10^{-12}$$

wich represents the orders of magnitude of the Compton wavelength (appendix). It is worth to remark that in a previous paper we used Avogadro's number , N_A . Still we do not have a proper definition of $(N_{...})$. Avogadro's number [1] describes the number of particles (atoms,molecules…) contained in one mole : $N_A = 6.02214\ x\ 10^{23}\ mol^{-1}$. Motivated by the search for a dimensionless number whose significant digits could match with those of N_A we have found the number $(N_{...})$.

If someone reads our previous article , which reads N_A must read $(N_{...})$. The latter has been obtained purely from physical and arithmetical parameters .

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Once described the two calculation tools will show several results . We have choose only a small set of subjects . An introductory sample wich opens the way to further developments .

In order to avoid the dispersal of the references concerning the physical constants , all physical constants used in this article are compiled in the appendix.

Results .

Surface's area of a particular sphere

Write the formula of the surface's area of a particular sphere [2]

$A_N = 4\pi r^2$, where $r = 4(N_{...})(o)$

$$A_N = 7.291746 \ x \ 10^{-21} \ m^2 \qquad (9)$$

Type now the surface's area of a particular Torus [3]

$$A_P = 4\pi^2 \left(l_p\right)\left(\frac{1}{2}\ l_p\right) = 5.15588 \ x \ 10^{-69} \ m^2 \qquad (10)$$

l_p stands for Planck's length (appendix). Figure 1 shows a view of the topic

Divide both equations

$$\frac{A_N}{A_P} = \sqrt{2} \ x \ 10^{48} \qquad (11)$$

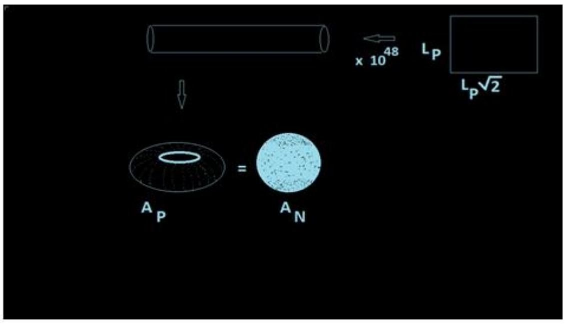

Figure 1

Now consider a cylinder whose volume is given by

$$V_{CP} = (\pi \, L_P^2)\ \frac{1}{4} L_P = \frac{1}{4}\ \pi L_P^3 \qquad (12)$$

L_P stands for Planck's length (appendix)

Suppose that such cylinder follows , while rotating , a circle whose radius is equal to L_P . Consequently the length of such circumference is equal to $2\pi \, L_P$ (figure 2). The resulting toroidal volume reads

$$V_{TP} = 2\pi \ L_P \ x \ V_{CP} = 2\pi^2 \frac{1}{4}\ L_P^4 \qquad (13)$$

Once defined V_{CP} and V_{TP} , write the following equivalence

$$(4)^4 \, (N_{...})^4 \, (o)^4 = V_{TP} \ x \ (10^{24})^4 \qquad (14)$$

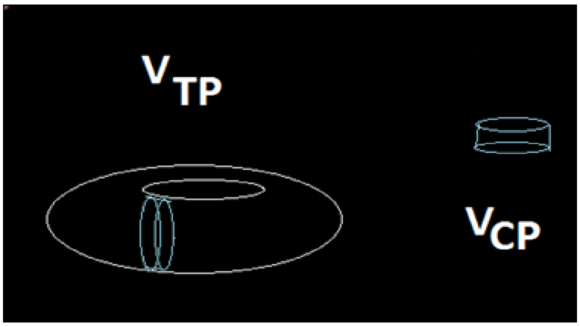

Figure 2 . ''Planck Torus''

Electrostatic force and gravitational force under the terms of a spacetime discrete

Write Newton's [4] formula of gravitational force between an electron and a proton

$$F_G = G_N \frac{m_e m_p}{r^2} \qquad (15)$$

Coulomb's law [5]of the electrostatic force reads

$$F_e = \frac{1}{4\pi\varepsilon_0}\frac{(Q)^2}{r^2} \qquad (16)$$

The values of the parameters involved in both equations are specified in the appendix.

After making the proper calculations , the ratio between gravitational force with respect to the electromagnetic force reads

$$\frac{F_G}{F_{EM}} = 4.4074 \, x \, 10^{-40} \qquad (17)$$

Now consider a basic sphere whose volume is given by

$V = \frac{4}{3}\ \pi \, r^3$

Will assign to the radius of such sphere the two values already defined

$r = 2(N_{...})(o)$

In the case at hand we must set $(N_{...}) = 6.02214 \ x \ 10^{24}$

Therefore

$r = 2(6.02214 \, x \, 10^{24})\left(\frac{1}{10^{35}}\right)$

Consequently

$$V = \frac{32}{3}\ \pi \, (N_{...})^3 \left(\frac{1}{10^{35}}\right)^3 \qquad (18)$$

Now consider a system made of a set of spheres V_N , obtained by multiplying the volume of the sphere V by $[(N_{...})(o)]$

$$V_N = [V][(N_{...})(o)] = \frac{32}{3}\ \pi \, (N_{...})^4 (o)^4 \qquad (19)$$

A simple calculation shows that

$$V_N = 4.4074 \, x \, 10^{-40} = \frac{F_G}{F_{EM}} \qquad (20)$$

Wich could be synthesized schematically as follow

$$F_{EM} \ x \ V_N \ \rightarrow \ F_G \qquad (21)$$

$$F_G \ x \ \frac{1}{V_N} \ \rightarrow \ F_{EM} \qquad (22)$$

Potential energy of an harmonic oscillator

Write the simplified formula of the potential energy of an harmonic oscillator [6]

$$U = \frac{1}{2}\ K \, x^2 \qquad (23)$$

since $K = m \, \omega^2$ we can express the potential energy as

$$U = \frac{1}{2}\ m \, \omega^2 \, x^2 \qquad (24)$$

will define two different potentials U_1 and U_2 and assign different values to each

$$U_1 = m_1 \ \omega_1^2 \ x_1^2 \qquad (25)$$

$m_1 = \frac{1}{10^{31}}\ kg$ same order of magnitude as the electron mass (appendix).

$\omega_1 = 10^{11} \ H_Z$ same order of magnitude as microwaves frequency.

$x_1^2 = A$ coincides with the surface's area of a particular Torus

$$A = 4\pi^2 \, R \, r \, (N_{...})^2 \qquad (26)$$

in which

$R = \frac{1}{10^{14}}\ m$ and $r = \frac{1}{10^{15}}\ m$ same order of magnitude as the classical electron radius

The second potential reads

$$U_2 = m_2\ \omega_2^2\ x_2^2 \quad (27)$$

$m_2 = \frac{1}{10^8}\ kg$ on the same level as the Planck mass (appendix)

$\omega_2 = 10^{43}\ H_Z$ same orders of magnitude as the Planck frequency (appendix)

$x_2 = 2l_p = 3.23232\ x\ 10^{-35}\ m$

Finally the result is equal to the inverse of the fine structure constant α (appendix)

$$\frac{U_1}{U_2} = \frac{10^{-31}\,kg}{10^{-8}kg}\ \frac{\frac{10^{22}}{s^2}}{10^{86}/s^2}\ \frac{4\pi^2\,(N_{...})^2}{(2l_p)^2} = \frac{1}{\alpha} \quad (28)$$

Entropy and granularity

Write the simple equation that describes the internal energy of a system .Assuming that each element has 2 active degrees of freedom [7]

$$U = n\,K_B\,T \quad (29)$$

In wich $n = 10^{46}$

K_B stands for Boltzmann constant (appendix) and T represents the temperature of the system

Write the formula of black hole entropy conjetured by Bekenstein and Hawking [8]

$$S_{BH} = \frac{K_B\ A}{4l_P^2} \quad (30)$$

Divide both equations

$$\frac{S_{BH}}{U} \rightarrow \frac{A}{4l_P^2}\frac{1}{n} = T \quad (31)$$

Define the surface's area of the events horizon

$$A = 4\pi\,R^2 \quad (32)$$

Apply discreteness parameters to the radius

$$R = \frac{1}{4}\ (N\,...)\ (o) \quad (33)$$

Hence

$$A = 2.848338\ x\ 10^{-23}\ m^2 \quad (34)$$

Therefore

$$\frac{A}{4l_P^2}\frac{1}{10^{46}} = \frac{2.848338\ x\ 10^{70}}{1.0448\ x\ 10^{70}} = 2.726\ K \quad (35)$$

The resulting value $T = 2.726\ K$ matches with the temperature associated to the CMB (cosmic microwave background) [9]

Cosmological constant

A common assumption consider that the cosmological constant is equivalent to the quantum vacuum energy density . It's known the issue between the theoretical value predicted for the cosmological constant and the experimental data about it . According to several sources [10] the observational value is around

$$\Lambda = \frac{1}{10^{52}m^2} \quad (36)$$

A value much smaller than theoretical values . For instance , will consider the case in wich the cosmological constant is written in terms of Planck units

$$\Lambda = \frac{1}{l_P^2} = 3.828\ x\ 10^{70}m^{-2} \quad (37)$$

l_P refers to Planck's length (appendix). It's obvious the huge discrepancy between experimental and theoretical values of Λ: the problematic 122 orders of magnitude that exists between them . Will describe a numerical development whereby the theoretical value $3.828\ x\ 10^{70}m^{-2}$ becomes equal to $3.83\ x\ 10^{-52}\ m^{-2}$ wich is close to the observed value .

For that , will analyze such topic by means of the Coulomb's law of the electric force

$$F_e = \frac{1}{4\pi\varepsilon_0}\ \frac{(Q)^2}{r^2} \quad (38)$$

will introduce the dimensionless parameters : (o) and $(N_{...}) = 6.02214\ x\ 10^{23}$ in the above equation

$$F_{e...} = \frac{1}{4\pi\varepsilon_0}\ \frac{(Q)^2(o)^2}{(o)^2}\ \frac{1}{(N_{...})u} = 3.8284\ x\ 10^{-52}\,\frac{1}{m^2} \quad (39)$$

Note that Parameter (o) computes both in the distance between charges and also in the elementary charge . We must remember that (o) is a dimensionless parameter , often associated with the length's unit used in this paper , $1m$.

As for the parameter $u = (1.0004\ \ Newton\ m^2)$ has been introduced for a proper cancellation of physical units . Consequently could write

$$\Lambda = F_{e...} \quad (40)$$

Resulting a value that agrees fairly well with the observational value of $10^{-52}\ m^{-2}$ and fit with the significant digits of the cosmological constant expressed as the inverse of squared Planck length . Wich means that cosmological constant could be the result of a repulsive force between electric charges Q (of the same sign) divided by each of the elements of a granular space . Such elements are defined by means of the dimensionless number $(N_{...})$.

Critical density of the Universe

Start writing the equation that defines the critical density of the Universe [11] at the current time

$$\rho_c = \frac{3H_0^2}{8\pi G} \quad (41)$$

H_0 refers to the Hubble constant = 67,775 $\frac{m/s}{M_{ps}}$ [12]

H_0 must be typed in metric units . It can be calculated by means of

$$\frac{H_0}{M_{ps}} = 2.1963\ \ x\ 10^{-18}\,\frac{1}{s} \quad (42)$$

M_{ps} refers to megaparsec . A parsec = $3.0857\ x\ 10^{16}\ m$ [13]

Symbol G refers to Newtonian constant of gravitation (appendix).

Hence

$$\rho_c = \ 8.6275\ \ x\ 10^{-27}\ \frac{kg}{m^3} \quad (43)$$

define other type of density

$$\rho_e = \frac{m_e}{V_C} \quad (44)$$

m_e stands for the electron mass (appendix)

V_C refers to the volume of a particular sphere whose radius is equal to the Compton wavelength (appendix)

$$V_C = \frac{4}{3}\ \pi\ (\lambda_C)^3 = 5.98312\ \ x\ 10^{-35}\ m^3 \quad (45)$$

Therefore

$$\rho_e = \ \frac{m_e}{V_C} = 15226.2\ \ \frac{Kg}{m^3}$$

Back to equation (41) instead of megaparsec will apply 10^3 parsec = $3.0857\ x\ 10^{19}\ \ m$.

In addition apply discreteness parameters $\frac{1}{8}[(N_{...})(o)]$. the result reads

$$\frac{H_0}{10^8 Ps}\,\frac{8}{(N_{...})\,(o)} = 2.91774\ x\ 10^{-3}\ s^{-1} \qquad (46)$$

Squaring

$$(2.9176\ x\ 10^{-3}\ s^{-1})^2 = 8.5132\ x\ 10^{-6}\ s^{-2} \qquad (47)$$

Introduce such value in the equation of critical density

$$\rho_{c...} = \frac{3(8.5124\ x\ 10^{-6} s^{-2})}{8\pi G}\,\frac{8}{(N_{...})^2}\,\frac{8}{(o)^2} = 15226.2\ \frac{Kg}{m^3} \qquad (48)$$

Hence

$$\rho_{c...} = \rho_e \qquad (49)$$

Electron angular momentum , quantum of action and granularity

For now we will type the simple formula for the electron angular momentum in a classical way[14]

$$L = m_e v\, r \qquad (50)$$

$v = 0.009997\ x\ c\ \frac{m}{s}$ c is the speed of light in vacuum and m_e the electron mass (appendix)

$r = 8\ x\ 10^{-11}\ m$ same orders of magnitude as the Bohr radius (appendix)

$L = 2.184\ x\ 10^{-34}\ J\,s$

Action , in physics , describes the overall motion of a particle or a system . Let us apply discreteness parameters to the unit of Action

$$L_{...} = [(N_{...})(o)]^3\ x\ 1\ J\,s\ =\ 2.184\ x\ 10^{-34}\ J\,s \qquad (51)$$

Hence there is a numerical equivalence between both actions (electron angular momentum and the action of a system made of discrete matters)

$$L = L_{...} \qquad (52)$$

Introduce a slight modification in (51) concerning the unit of Action

$$L_{...} = [(N_{...})(o)]^3\ x\ \left(\frac{1}{10}\right)\ J\,s\ =\ 2.184\ x\ 10^{-35}\ J\,s \qquad (53)$$

Such arithmetic change allow us to write

$$[L_{...}\sqrt{2}\ +\ L_{...}] = \frac{1}{2}\,\hbar \qquad (54)$$

$\hbar$ refers to reduced Planck constant .

Will explore briefly a relationship between the energy (by means of the quantum of Action) and the geometry .Type the Surface area of a Torus

$A\ ... = 4\,\pi^2 R\, r$ in wich $r = (N_{...})(o)$ and $R = 2r$

As for the energy will apply te equation conjetured by Einstein and Planck

$E = \hbar\, v$

$\hbar$ refers to the reduced Planck constant (appendix) and v stands for the frequency

Set $v = 1.59896\ x\ 10^{11}\ \frac{1}{s}$ (close to the CMB)

Write a constant value

$$Q = \frac{2}{10^{44}}\ J\,m^2 \qquad (55)$$

Therefore

$$A\ ... = \frac{1}{E\sqrt{2} - E}\ \ Q \qquad (56)$$

It's easy to convert the surface's area of a Torus on the surface's area of a sphere

$$AS\ ... = 4\pi r^2\,(S\ ...) = \frac{1}{\hbar v}\,\frac{\sqrt{3}}{2\sqrt{2}}\ \ Q \qquad (57)$$

Where $S_{...} = (\,1 + \frac{1}{2} + \frac{1}{16} + \frac{1}{32})$

The radius of the sphere $r = (N_{...})(o)$. As for the frequency $v =\ 1.59896\ x\ 10^{11}\ \frac{1}{s}$

The left side of the equation (57) could be figured as a set of the four surfaces of four spheres, as it is shown in the figure 3 (after a cut at the center).

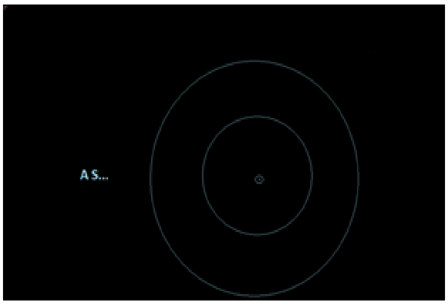

Figure 3

While the frequency increases the energy increases , consequently the radius diminish and consequently surface's area decreases .

Type the general equation that summarizes the hypothesis of a dynamic balance between two energies .The energy of the quantum tends to collapse the system while the repulsive electrostatic energy associated to the cosmological constant offsets the first one

$$hv\,(\frac{1}{4}N_{...})^2\,(o)^2\,B\,w\ =\ \Lambda \qquad (58)$$

h refers to the Planck constant .The frequency $v = 1.59896\ x\ 10^{11}\ \frac{1}{s}$.

B is a dimensionless variable

$B = S_{...}\,10^n$

where $n = (... - 3, -2. -1, 0, 1, 2, 3\ ...)$. In the case at hand $n = -6$, hence

$$B = \frac{1}{10^6}\,(\,1 + \frac{1}{2} + \frac{1}{16} + \frac{1}{32}) \qquad (59)$$

As for the parameter $w = (\frac{1.00035}{J\,m^2})$ has been introduced for a proper cancellation of physical units .

The observational value of the cosmological constant expressed in Planck's units

$\Lambda = 3.8284\ \frac{1}{10^{52}\,m^2}$

Assuming the hypothesis of a cosmological constant that not change over time . Assuming that the energy of a OPEN system change over time . Suppose that parameter B varies over time . Therefore

$$[hv\,\left(\frac{1}{4}N_{...}\right)^2\,(o)^2\,B\,w\,] - \Lambda = 0 \qquad (60)$$

Discussion.

Definition of the parameter of discreteness $(N_{...})$ are based on physical constants only . As for the first approach to $(N_{...})$, wherein the result is equal to $(N_{...}) = 6.02214\ x\ 10^{30}$, would think about a particular case in wich the energy equivalent of the proton mass is divided by an amount of 10^7 photons . Then will obtain $(N_{...}) = 6.02214\ x\ 10^{23}$.

Also would imagine a system in wich the speed of light becomes 10^7 times slower than the speed of light in vacuum. the result is the same as in the previous case .

The first two paragraphs describe geometrical equivalences involving plane , Surface , sphere and Torus . It allow us to link up the volume of a Torus drawn to scale of Planck with a 4-dimensions volume in wich $(N_{...})$ and (o) are involved. Besides the presumption of a discrete spacetime , we have developed this paper taking the premise of four dimensions Universe .

The issue of cosmological constant was approached by means of the Coulomb law of the electostatic potential energy . Since we assumed a spacetime granular , what about if the units of such fabric could hold electric charge ? Based on this presumption we could write a numerical link between the cosmological constant and the electrostatic energy between charges of the same sign , wich leads a repulsive force . The result obtained by means of the Coulomb's law together with $(N_{...})$ agrees with the observed value for the cosmological constant .

The topic about black hole entropy could be figured as a numerical eqivalency . Shortly , the entropy of a system containing 10^{46} particles , each one of them has two degrees of freedom, is the same as a black hole whose surface's area of the events horizon is made of discrete elements . More , temperature associated with such system is the same as temperature associated with the cosmic microwave background .

Paragraph devoted to analyze critical density of the Universe pursue a numerical equivalence between two densities . We introduced discreteness parameters in the formula of the critical density .Outcome of such operation agrees with the density of an electron as defined in (44)

The ratio between gravitational force and electrostatic force , potential energy of harmonic oscillator have been analyzed applying criteria of discreteness also.

Conclusion.

We have typed several numerical approachs that regard the observable Universe as made of discrete matters : relality could be as a grid and a four dimensions spacetime could be analyzed under a *granular* point of view . For that we used two parameters . Some cosmological estimations have been dissected . This is a preliminary focusing at the Universe discreteness. Will inquire further developments .

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Appendix

Physical constants [15]
Elementary charge , Q : $1.602176\ x\ 10^{-19}\ J$
Electric constant , ε_0 : $8.854187817 \ldots x\ 10^{-12}\ \frac{C^2}{Nm^2}$
Planck length , l_P : $1.6162\ x\ 10^{-35}\ m$ Planck mass , m_P : $2.1765\ x\ 10^{-8}\ kg$ Planck angular frequency , ω_P : $1.855\ x\ 10^{43}\ s^{-1}$ Planck constant , $h = 6.62607\ x\ 10^{-34}\ Js$ Reduced Planck constant , $\hbar = \frac{h}{2\pi}$
Speed of light in vacuum , c : 299792458 $\frac{m}{s}$
Newtonian constant of gravitation , G_N : 6.6735 $x\ 10^{-11}\ \frac{m^3}{kg\ s^2}$
Boltzmann constant $K_B = 1.38065\ \frac{J}{K}$
Proton mass , m_p : $1.67262\ x\ 10^{-27}\ kg$ Electron mass , m_e : $9.109382\ x\ 10^{-31}\ kg$ Compton wavelength , λ_c : $2.42631\ x\ 10^{-12}\ m$ Proton Compton wavelength , λ_{cp} : $1.32141\ x\ 10^{-15}\ m$ Classical electron radius , r_e : $2.81794\ x\ 10^{-15}\ m$ Bohr radius , a_0 : $5.291772\ x\ 10^{-11}\ m$ Fine structure constant , α : 0.007297353