Universe Discrete and Reality Granular .

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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.

Keywords . Discreteness , Reality , Classical physics .

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 the Planck's scale . Will typify such parameter as

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

The second parameter is defined below

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

a represents the proton frequency, resulting from the formula

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

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

$$b = S_{...} + \frac{S_{...}}{10} + \frac{S_{...}}{10^2} + \frac{S_{...}}{10^3} + \cdots \tag{3}$$

where

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

Consequently $b = 0.885417$

Strictly speaking 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.

$$d = 1 \ \frac{s^2}{m} \tag{5}$$

Write a dimensional analysis of the equation (1)

$$[a][c][d] = \ [T^{-1}] \ [LT^{-1}] \ [\ L^{-1}T^2] \tag{6}$$

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

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

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

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

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 .

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 $r = 4(N_{...})(o)$

$A_N = 7.291746 \times 10^{-21} \; m^2$ \hfill (9)

Surface's area of a particular Torus [3]

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

l_p stands for Planck's length (appendix).

Divide both equations

$\frac{A_N}{A_P} = \sqrt{2} \times 10^{48}$ \qquad below a depiction of the topic \hfill (11)
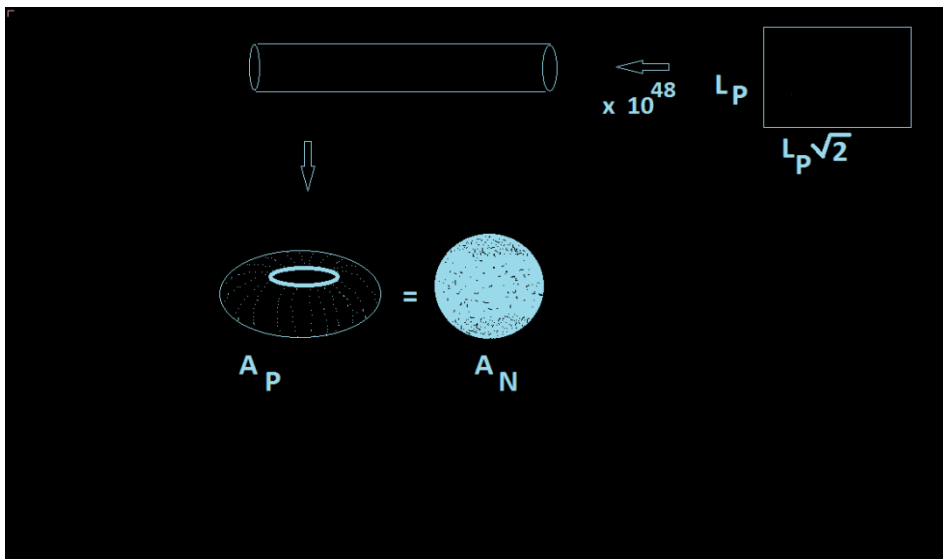

Figure 1.

Now consider a cylinder whose volume is given by

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

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

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

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

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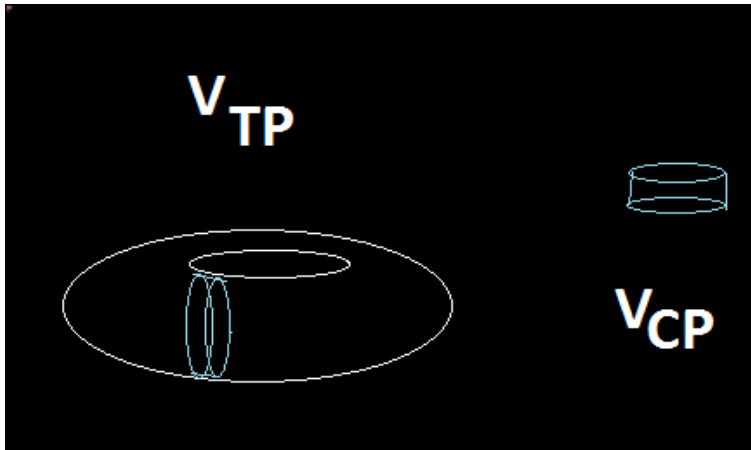

Figure 2. ''Planck Torus''.

Forces ratio .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

$$F_G = G_N \frac{m_e \ m_p}{r^2} \tag{15}$$

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

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

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

$$\frac{F_G}{F_{EM}} = 4.4074 \; x \; 10^{-40} \tag{17}$$

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

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

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

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

A simple calculation shows that

$$V_N \; = 4.4074 \; x \; 10^{-40} = \frac{F_G}{F_{EM}} \tag{20}$$

Wich could be synthesized schematically as follow

$$F_{EM} \; x \; V_N \; \rightarrow \; F_G \tag{21}$$

$$F_G \; x \; \frac{1}{V_N} \; \rightarrow \; F_{EM} \tag{22}$$

Potential energy of an harmonic oscillator

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

$$U = \frac{1}{2} K \, x^2 \tag{23}$$

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

$$U = \frac{1}{2} m \, \omega^2 \, x^2 \tag{24}$$

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

$$U_1 = m_1 \, \omega_1^2 \, x_1^2 \tag{25}$$

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

$\omega_1 = 10^{11} \, H_Z$ on the same level as microwaves frequency.

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

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

in wich

$$R = \frac{1}{10^{14}} \, m$$

and $r = \frac{1}{10^{15}} \, m$ on the same level as the classical electron radius

The second potential reads

$$U_2 = m_2 \, \omega_2^2 \, x_2^2 \tag{27}$$

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

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

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

l_p refers to Planck's length (appendix).

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

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

 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]

$$U = n \, K_B \, T \tag{29}$$

In wich $n = 10^{46}$

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

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

$$S_{BH} = \frac{K_B \, A}{4l_P^2} \tag{30}$$

Divide both entropies

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

Define the surface's area of the events horizon

$$A = 4\pi \, R^2 \tag{32}$$

Apply to the radius discreteness parameters

$$R = \frac{1}{4} \, (N \ldots) \, (o) \tag{33}$$

Hence

$$A = 2.848338 \; x \; 10^{-23} \; m^2 \tag{34}$$

Therefore

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

The resulting value $T = 2.726 \; K$ matches with the temperature associated to 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

$$\Lambda = \frac{1}{10^{52} m^2} \tag{36}$$

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

$$\Lambda = \frac{1}{l_P^2} = 3.828 \; x \; 10^{70} m^{-2} \tag{37}$$

l_P refers to Planck's length (see 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

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

in witch $r = 1\, m$

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

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

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

$$\Lambda = F_{e...} \tag{40}$$

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

$$\rho_c = \frac{3H_0^2}{8\pi G} \tag{41}$$

H_0 refers to the Hubble constant = 67,774 $\frac{m/s}{M_{ps}}$ [12]

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

$$\frac{H_0}{M_{ps}} = 2.1963\ x\ 10^{-18} \frac{1}{s} \tag{42}$$

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

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

Hence

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

define other type of density

$$\rho_e = \frac{m_e}{V_C} \tag{44}$$

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)

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

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

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

Squaring

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

Introduce such value in the equation of critical density

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

Hence

$$\rho_{c...} = \rho_e \tag{49}$$

Electron angular momentum , quantum of action and granularity

For now we will just write some equations . Further developments of this subject are required.

Type the simple formula for the electron angular momentum in a classical way[14]

$$L = m_e v \, r \tag{50}$$

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

$$r = \; 8 \; x \; 10^{-11} \, m$$

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

Apply discreteness parameters

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

Hence

$$L = \; L_{...} \tag{52}$$

A quantified view

$$L_{...} = 5 (\hbar\sqrt{2} - \hbar)$$ (53)

Equal to

$$\frac{1}{5} [L_{...} \sqrt{2} + L_{...}] = \hbar$$ (54)

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 . Astronomical continuous measurement , parsec , turn discrete .Outcome of such operation agrees with the density of an electron as defined in (44)

The rest of the subjects , the ratio between gravitational force and electrostatic force , potential energy of harmonic oscillator , they 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   : $1.602176 \times 10^{-19}\,J$
Electric constant , ε_0 : $8.854187817 \ldots \times 10^{-12}\,\frac{C^2}{Nm^2}$
Planck length , l_P : $1.6162 \times 10^{-35}\,m$ Planck mass , m_P : $2.1765 \times 10^{-8}\,kg$ Planck angular frequency , ω_P : $1.855 \times 10^{43}\,s^{-1}$
Speed of light in vacuum , c : $299792458\,\frac{m}{s}$
Newtonian constant of gravitation , G_N : $6.6735 \times 10^{-11}\,\frac{m^3}{kg\,s^2}$
Boltzmann constant $K_B = 1.38065\,\frac{J}{K}$
Proton mass , m_p : $1.67262 \times 10^{-27}\,kg$ Electron mass , m_e : $9.109382 \times 10^{-31}\,kg$ Compton wavelength , λ_c : $2.42631 \times 10^{-12}\,m$ Proton Compton wavelength , λ_{cp} : $1.32141 \times 10^{-15}\,m$ Classical electron radius , r_e : $2.81794 \times 10^{-15}\,m$ Fine structure constant , α : 0.007297353