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GRAVITO-ELASTICITY. ACCELERATED EXPANSION OF THE UNIVERSE

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This article is an attempt to unify the theories of gravity and elasticity and proposes a novel approach for Space-time, and more generally Cosmology. The primary hypotheses of the study is that universal Space-time deforms elastically under the influence of gravity, of matter in general, as also proposed by Einstein's Theory of relativity. This is a novel approach whereby space-time is analyzed as if it would be a physical object endowed with elasticity and it could responding elastic to the matter action. This behavior would be in total agreement with the Principle of Action and Reaction. Within this new and complementary theoretical framework we will analyze certain fundamental cosmological aspects: the scale factor, Hubble's Law, time dilation, deflection of light, accelerated expansion of the Universe. The ensuing theory that studies the elasticity of space-time and it's response to gravity is named "gravito-elasticity". Its principles are new and therefore the specific bibliography is rare, with the notable exceptions of [2], [7], [8] and [9] where the authors also study the elastic deformability of space-time. The verification of the gravito-elastic principles is achieved in comparison with similar results in modern cosmology. These results validate the choice of elastic characteristics for space-time (already introduced in [2]) namely Y_0- the space-time's Young elasticity modulus and K_Ω- the space-time's elasticity constant.

Keywords : Gravity , Cosmology, Big-Bang, Hubble's Law, scale factor, time dilatation, light deflection, expansion of the Universe .

1. Introduction

It is well-known from Einstein's General Relativity Theory (GRT) that Space-time and matter influence each other in the Universe ([1] , [7],) . J.A.Wheeler stated- [5] that "Space-time tells matter how to move; matter tells Space-time how to curve." In 1955, the Italian mathematician Bruno Finzi postulated in [6] the Principle of Solidarity: " It is necessary to consider space-time to be solidly connected with the physical phenomena occurring in it, so that its features and its very nature do change with the properties thereof. In this way not only space-time properties affect phenomena, but reciprocally phenomena do affect space-time properties. ". In agreement with the Principle of Action and Reaction came the question about the Space-time reaction to the matter's gravitational deformation . Some works like [2] , [7] , [8], [9] they have already begun to answer to this by unifying the GRT with the Elasticity Theory . In article -[2] we introduce the idea of studying **elastic deformability** of space-time,

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by means of its assimilation with a certain "physical substance" possessing the regular features of an elastic body as described by the Theory of Elasticity. Hence the elastic response of the space-time to the gravitational matter's action would be in total agreement with the Principle of Action and Reaction. More specifically, in [2] we introduce two new physical constants defining the elastic behavior of the Space-time (of the Universal Vacuum):

1) The elastic (Young) modulus of Vacuum, which must meet the following conditions: -Solely dependent on fundamental physical constants of the universe (c-speed of light and the gravitational constant-G)-Dimensionally measured in N /m^2 - Have the simplest form possible (Occam's principle).

Therefore in [2] we have proposed the following expression for Young modulus for the Cosmic vacuum:

$$Y_0 \stackrel{\text{def}}{=} \frac{1}{\chi \cdot S_U} = \frac{1}{\chi \cdot \pi \cdot R_U^2} = 9 \cdot 10^{-12}\ \mathrm{N/m^2} \qquad (1)$$

where the Einstein's gravitational coupling constant: $\chi = \frac{8\pi G}{C^4} \cong 2 \cdot 10^{-43}\ \frac{S^2}{m \cdot kg}$

and the section of the Universe-sphere-S_U was computed based on the current radius of the Universe $R_U = 4.2 \cdot 10^{26}$ m .

2) Also in [2] we introduced K_Ω- the elasticity constant of certain Space-time domain, submitted to an elastic deformation. If it has the transverse area of the deformation direction $=S_\Omega$ and the length on the deformation direction $=L_\Omega$, then the elasticity constant:

$$K_\Omega \stackrel{\text{def}}{=} Y_0 \frac{S_\Omega}{L_\Omega} \qquad (2)$$

thus, it meets the dimensionality conditions (N/m) depending on the geometry and also on the "material features" of the Vacuum domain.

3) The correctness of the definition (1) was verified by computing the maximum propagation speed of a perturbation through a certain environment according to the formula of the Elasticity Theory [4]:

$$c = \sqrt{\frac{Y_0}{\rho_0}} = \sqrt{\frac{9 \cdot 10^{-12} N/m^2}{10^{-28} Kg/m^3}} = 3 \cdot 10^8 m/s \quad \text{or} \quad Y_0 = c^2 \cdot \rho_0 \qquad (3)$$

where the density value of the Vacuum was deemed $\rho_0 = 10^{-28} Kg/m^3$= to the average density of the Universe. It is obvious that in the Cosmic Vacuum the maximum propagation speed of any perturbation is the speed of light "c".

Consequent to the ideas above, this article further analyses essential aspects of Cosmology, based on the hypothesis of Universe's elasticity supported by the principles of Classic Theory of Elasticity [4]. The results obtained will be compared with those of the gravity ([1],[3]) and the generic name of "*gravito-elasticity*" is used throughout the article for this type of approach of Cosmology.

2. Cosmological parameters determination using gravito-elasticity hypotheses .

2.1 Universe's mass . Scale factor. Hubble's constant.

For this we shall now detail the total energy of the Universe, considering that it is a closed physical system: Total energy = Kinetic energy +Potential elastic energy

$$Mc^2 = N\,k\,T + \frac{K_U\cdot(2R_U)^2}{2} \tag{4}$$

where: $\boldsymbol{M_U c^2}$- the Total Energy is the well-known formula of Einstein (M_U –the total mass of the Universe) (5)

$\boldsymbol{N\cdot k\cdot T} = \frac{M_U}{m_p}\cdot k\cdot T$ = the internal thermal kinetic energy of the Universe; (N= $\frac{M_U}{m_p}$ - total number of elementary particles in the Universe; ; $m_p = 1.67\ \cdot 10^{-27} kg$ - proton's mass; ; k = $1.38\cdot 10^{-23}$J/K – Boltzmann's constant;

T= $2.7°K$ average basic temperature of the Universe) (6)

$\frac{\boldsymbol{K_U\cdot(2R_U)^2}}{\boldsymbol{2}}$ --the Elastic Deformation Potential Energy of Universe (7)

-using (1)+(2) :

$$K_U = Y_0\frac{S_U}{2R_U} = \frac{1}{\chi\cdot S_U}\frac{\cdot S_U}{2R_U} = \frac{1}{2\chi R_U} \tag{8}$$

- the average radius of the observable Universe it is $R_U = 4.2\ \cdot\ 10^{26}$ m

Now introducing (5),(6), (7) and (8) in (4) we obtain:

$$M_U c^2 = \frac{M_U}{m_p}\cdot k\cdot T + \frac{R_U}{\chi} \tag{9}$$

since $\frac{M_U}{m_p}\cdot k\cdot T \approx\ 10^{57} j\ \ll \frac{R_U}{\chi} \approx 10^{69} j$, finally the Universe's mass

$$M_U \simeq \frac{R_U}{c^2\cdot\chi} \simeq 10^{52} kg \tag{10}$$

The (10)-value for Universe's mass is similarly with that accepted in Cosmology and here was calculated only introducing in the Universal Energy-(4) the formula for Elastic Deformation Energy of the Universe- (7).

Further we consider the scale factor- $a(t)$ known from the FRW metric (Friedmann-Robertson-Walker) [1],[3]. This scale factor shows how changes over time the distance between 2 galaxies . Considering -r- the physical distance from "origin" to a certain galaxy, we may write a radial coordinate function -(independent of time) as follows :

$$r \stackrel{\text{def}}{=} a(t)R_U \tag{11}$$

The theory also defines the Universe expansion constant = Hubble's constant-H [3], as follows :

$$H \stackrel{\text{def}}{=} \frac{\dot{a}(t)}{a(t)} \tag{12}$$

Further on, we shall determine the evolution equation of the scale factor- $a(t)$ and Hubble's constant to today's value, taking into account only the work hypotheses of gravito-elasticity. We will consider the Universe as a deformable-elastic physical object, in expansion; thus, we may determine its Lagrange function :

$$\mathcal{L}_U = \mathcal{L}_{Ukinetic} + \mathcal{L}_{Uelastic} = \frac{M_U\dot{D}^2}{2} + \frac{K_U D^2}{2} = \frac{M_U(\dot{2r})^2}{2} + \frac{K_U(2r)^2}{2} \quad (13)$$

(where, obviously, D=2r is actually the Universe's diameter).

We shall now write the Euler-Lagrange equations based on the equations (13) and (2):

$$\frac{d}{dt}\left(\frac{\partial\mathcal{L}_U}{\partial\dot{r}}\right) - \frac{\partial\mathcal{L}_U}{\partial r} = \left(2M_U\ddot{r} + 2\dot{M}_U\dot{r}\right) - \frac{\partial(Y_0\frac{4\pi r^2}{r}\cdot\frac{(2r)^2}{2})}{\partial r} = 0 \quad (14)$$

Meaning that the elastic Universe's Euler-Lagrange equation may be simplified :

$$M_U\ddot{r} + \dot{M}_U\dot{r} - 12Y_0\pi r^2 = 0 \quad (15)$$

if we work in the hypothesis of mass-conservation in the Universe, than in (15) the term $\dot{M}_U\dot{r} = 0$ and using the expression (10) for M_U we get :

$$\frac{\ddot{r}}{r} = 12\pi Y_0\chi c^2 \quad (16)$$

now using (11)-the definition of the scale factor we get

$$\frac{\ddot{r}}{r} = \frac{\ddot{a}(t)}{a(t)} \quad (17)$$

and, moreover, from (12)- the definition of Hubble's constant:

$$\ddot{a}(t) = H\cdot\dot{a}(t) \quad (18)$$

from where, replacing in equation-(16) it results the value of Hubble's constant:

$$\frac{\ddot{r}}{r} = \frac{\ddot{a}}{a} = \frac{\ddot{a}}{\dot{a}}\cdot\frac{\dot{a}}{a} = H^2 = 12\pi Y_0\chi c^2 \;\Rightarrow\; H = \sqrt{12\pi Y_0\chi c^2} = 0.25\cdot 10^{-17}sec^{-1} \quad (19)$$

the value (19) obtained for H is exactly the standard one accepted nowadays. To determine the dynamic of the scale factor- we shall introduce into the Euler-Lagrange equation (15) the formula-M from (10), formula-Y_0 from (1) and the definition – $a(t)$ from (11) hence:

$$\ddot{r}/r + (\dot{r}/r)^2 = 4\pi\chi c^4\rho_0(t) \text{ or: } \ddot{a}/a + (\dot{a}/a)^2 = 4\pi\chi c^4\rho_0(t) \quad (20)$$

The equation (20) is the equivalent of Friedmann's equation of GRT and indicates the dynamic of the scale factor-depending on time. In the particular case of radiation dominance in the Universe, we consider in the right-side term (20) $\rho_0(t) \longrightarrow 0$ that (20) as well becomes a non-linear and homogeneous equation:

$$\ddot{a}/a + \left(\dot{a}/a\right) = 0 \text{ with a solution : } a(t) = a_0\cdot\sqrt{t} \quad (21)$$

solution similar to the one of Friedmann's equation ([1],[3]).

2.2 Gravito-elasticity equation.

The main idea of this article is represented by the concept of an elastic behavior of Space-time to a gravitation-induced deformation. Basically, when a cosmic object of -M mass gravitationally contracts the Space-time sphere centered in the middle of -M, the Space-time "opposes" this deformation with an elastic force even and contrary to gravitation (Fig 1). Mathematically speaking, the gravitational potential and the elastic potential of Space-time must be equal:

$$d\Phi \equiv d\Phi_{ELST} \qquad (22)$$

More explicitly, we consider the case of a certain cosmic object of M mass that at a distance -r elastically deforms the Space-time around -(meaning it contracts the surface of the Vacuum sphere having the radius-r with the amount-$\triangle r$). In this regard, we may consider the gravito-elastic force as being a force of "inertial" type since it tends to preserve the situation previous to the gravitational compression .

The identity (22) computed at the distance-r from the center of the cosmic object is:

$$\boldsymbol{d}\left(\frac{\boldsymbol{G\cdot M\cdot m_\Omega}}{\boldsymbol{r}}\right) \equiv \boldsymbol{d}\left(\frac{\boldsymbol{K_\Omega\cdot(\triangle r)^2}}{\boldsymbol{2}}\right) \qquad (23)$$

obviously in (23) $\boldsymbol{m_\Omega}$ and $\boldsymbol{K_\Omega}$ are, respectively, the mass and the elastic constant of the Vacuum sphere (Space-time sphere) of radius –r- and centered in the middle of the cosmic object of M---mass. Taking into account the relations defining**:**

- G= 6.67 $\cdot\ \boldsymbol{10^{-11}\, m^3/kg/s^2}$ the constant of the universal gravity
- $\boldsymbol{m_\Omega = \frac{4\pi r^3}{3}\cdot\rho_0}$ the mass of Vacuum sphere of radius-r
- elasticity constant (2) of the Vacuum sphere (diameter=2r)

$\boldsymbol{K_\Omega = Y_0\frac{S_\Omega}{L_\Omega} = c^2\cdot\rho_0\frac{4\pi r^2}{2r}}$ (it was taken into account in the definition : formula-(2) that in the case of a radial-symmetric deformation of the Vacuum sphere, the transverse area of the elastic deformation is actually the surface of the sphere $\boldsymbol{S_\Omega = 4\pi r^2}$; but also (3)-expression : $\boldsymbol{Y_0 = c^2\cdot\rho_0}$)

- the Schwarzschild radius of the M mass cosmic object: $r_S \stackrel{\text{def}}{=} \frac{2GM}{c^2}$.

We shall replace this measures in (23) and after differentiation and simplifications it results:

$$\frac{d((\triangle r)^2)}{dr} + \frac{(\triangle r)^2}{r} - \frac{4r_S}{3} = 0 \qquad (24)$$

The differential equation-(24) is the central equation of this study. It is a classical D'Alembert equation and by integration leads to:

$$\triangle r = \sqrt{\frac{C_1}{r} + \frac{2r_S}{3}r} \qquad (25)$$

Where, in order to determine the integration constant-C_1 , we shall put the condition that for the r=r_S Schwarzschild radius, the deformation reaches and extreme value, therefore :

$$\left(\frac{d(\Delta r)}{dr}\right)_{r=r_S} = 0 \qquad (26)$$

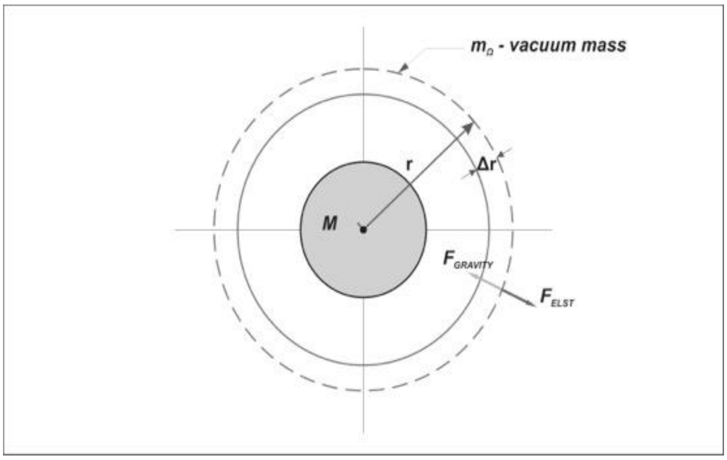

Fig. 1 . Vacuum sphere gravito-elastic contracted by a M-mass Cosmic object

This leads to $\boldsymbol{C_1}=\frac{2r_S^3}{3}$ and the final expression of the Vacuum sphere deformation (of the Space-time) of -r radius centered around the cosmic object of -M mass measured at a certain -r distance from the center of the -M object becomes:

$$\Delta r = \sqrt{\frac{2r_S^3}{3}\Big/r + \frac{2r_S}{3}\cdot r} \qquad (27)$$

This elastic deformation is produced by the presence of -M matter concentration. In the case of a homogeneous -M object and taking into account the homogeneity and isotropy of the Space-time, the Vacuum sphere centered in M and the initial radius=r, shall be radially-symmetrical contracted with Δr. Obviously, the expression (27) also verifies another condition (weaker than (26)) that in the absence of matter (M=0, therefore $r_S = \frac{2GM}{c^2}$ =0) the deformation of the $\text{Space} - \text{time}\ \Delta r = 0$! Namely, exactly like in the case of GRT, in the absence of matter, the Universe if flat, Minkowskian . Further, analyzing the expression (27) we must recall that when a-M mass body gravitationally contracts the Space-time around, the latter opposes with an elastic-type force proportional to the deformation .

$$\overrightarrow{F_{GRAVIT}} = -\overrightarrow{F_{ELST}} = K_{\Omega} \cdot \Delta r = K_{\Omega}\sqrt{\frac{2r_S^3}{3}\Big/r + \frac{2r_S}{3} \cdot r} \quad (28)$$

1) The first term below the radical $\left(\frac{2r_S^3}{3}\Big/r\right)$ in (28) is the “gravitational” component of the gravito-elastic force and contains -r - to a denominator and shows us that when $r \longrightarrow 0$, although, the gravitational compression increases very much, the Space-time from the center of the -M body opposes elastically to the deformation with the same force. Therefore, it is possible that the black-hole gravitational collapse does not always occur. This first term is dominant inside and near the cosmic object.

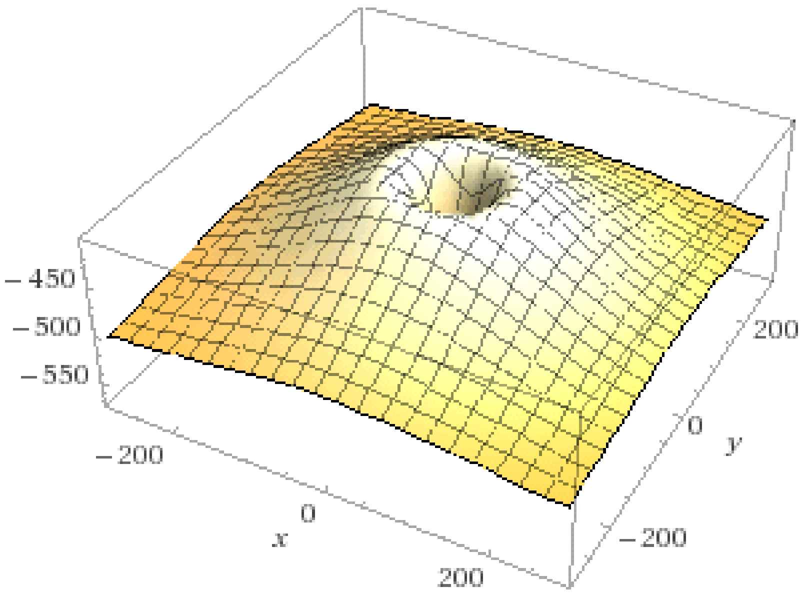

Fig. 2- –the Sun deforms the Space-time in its vicinity (plotting with Wolfram according to the function : f(r) = r − Δr (r= the position vector ; Δr= gravito-elastic deformation formula (27) ; Sun’s Schwarzschild radius ≃ 3000m)

2) The second term in (28),below the radical, ($\frac{2r_S}{3} \cdot r$) it’s the “pure-elastic” component and increases to infinity when $r \longrightarrow \infty$. Here it is clearly shown the elastic nature of this force, which increases in intensity by increasing the distance (somehow similarly to the “nuclear interaction” force in the nucleus of the atom). However, it is a novelty in Cosmology that an interaction, becomes stronger with increasing distance from the gravitation source-M! In fact, as far as we go from the -M source, the Space-time puts a stronger elastic opposition to its deformation by -M.

2.3 Temporal dilation

A well-known aspect of Cosmology is the dilation phenomenon of the time frame corresponding to a physical system found in the gravity field of a -M mass cosmic object. The formula from the GRT-[1] for the calculation of this temporal dilation :

$$\Delta t = \sqrt{1-\frac{2\Phi}{c^2}}\cdot\Delta t_0 = \sqrt{1-\frac{2\mathrm{GM}}{c^2 r}}\cdot\Delta t_0 = \sqrt{1-\frac{r_S}{r}}\cdot\Delta t_0 \qquad (29)$$

Where Δt_0- is the corresponding time measured with a standard clock in an area without matter (whereby $\Phi = 0$) and Δt-it is the corresponding time measured in the gravity field of an M mass cosmic object (whereby $\Phi = \frac{GM}{r} \neq 0$).

Further, we shall deduce the formula of temporal dilation using the principles of gravito-elasticity. In this regard, we shall deem a “world line” (geodesic) which, in the absence of matter, is rectilinear. The same world line (geodesic) in the vicinity of an M-mass cosmic object is elastically deformed towards the center of the -M object with the distance- Δr under the form of a hyperbolic arc. In Fig 3. from the resemblance of the triangles OAC and OBD results:

$$\frac{BD}{AC} = \frac{OD}{OC} \Longrightarrow \frac{\frac{\Delta l_0}{2}}{\frac{\Delta l}{2}} = \frac{r}{r-\Delta \mathrm{r}} \qquad (30)$$

On the other side, the length of the line element of a geodesic is:

$$ds^2 = c^2dt^2 - dl^2 = c^2dt_0^2 - {dl_0}^2 = 0 \qquad (31)$$

From (30)and(31): $\frac{\Delta t_0}{\Delta t} = \frac{\Delta l_0}{\Delta l} = \frac{r}{r-\Delta \mathrm{r}} \Longrightarrow \Delta t = (1-\frac{\Delta r}{r})\Delta t_0$ (32)

Now, we shall introduce the expression of-Δr from (27) into the equation (32) :

$$\Delta t = \left(1 - \frac{\sqrt{\frac{2r_S^3}{3}\Big/ r + \frac{2r_S}{3}\cdot r}}{r}\right)\Delta t_0 = (1-\sqrt{\frac{2r_S^3}{3r^3}+\frac{2r_S}{3r}})\cdot\ \Delta t_0 \qquad (33)$$

Observation :for an average star, like the Sun, for example, the ratio: $\frac{r_S^3}{r^3} = \frac{(3000m)^3}{(700000000m)^3} \simeq 8\cdot\ 10^{-17} \ll \frac{r_S}{r} \simeq 4\cdot 10^{-6}$; that is why, when we study temporal dilation outside the frontier of the M-mass cosmic object : $r > r_M \gg r_S$ and we may neglect in (33) the ration--($\frac{2r_S^3}{3r^3}$) below radical !

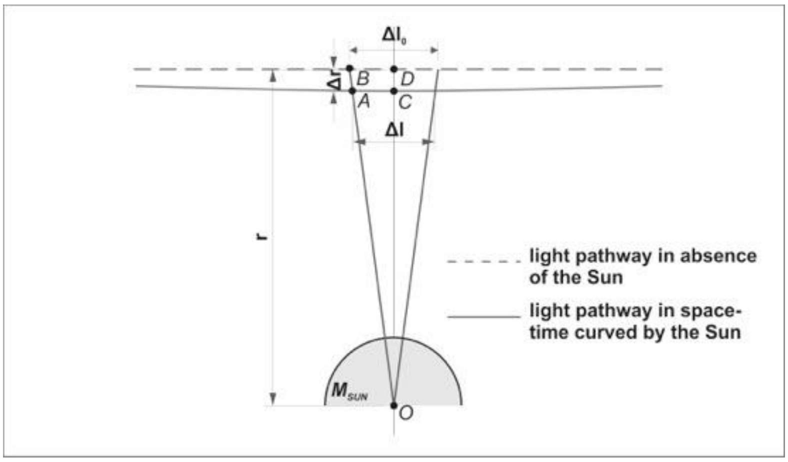

Fig. 3 . The light pathway curved by the Sun

than the expression of temporal dilation is reduced to:

$$\Delta t = (1 - \sqrt{\frac{2r_S}{3} \cdot 1/r})\, \Delta t_0 = (1 - \sqrt{\frac{4\Phi}{3c^2}}) \cdot \Delta t_0 \qquad (34)$$

This expression-(34) is the equivalent of the temporal dilation equation (29) of the GRT. In the particular case of a standard clock found on Earth, the temporal distortion caused by the Sun shall depend on: the Sun's mass: $M_{SUN} = 2 \cdot 10^{30} kg$; the radius Schwarzschild Sun : $r_S = \frac{2GM_{SUN}}{c^2} \simeq 3000m$; the distance from the Sun to the Earth (where the measurement would be performed) r$\simeq 15 \cdot 10^{10} m$.

-within GRT we shall apply the formula (29) and obtain

$$\frac{\Delta t_0}{\Delta t} = 1.0000002 \qquad (35)$$

- within the gravito-elastic we apply the formula (34) and we obtain a temporal dilation report due to the presence of the Sun:

$$\frac{\Delta t_0}{\Delta t} = 1.00002 \qquad (36)$$

The difference between the 2 values is sufficiently small to consider that it comes from the approximation of the physical values used and also from the geometrical approximation in **Fig 3** : $\widehat{AC} \simeq \overline{AC}$ (the curve-$\widehat{AC} \simeq \overline{AC}$-the line segment).

2.4 Light Deflection

Another well-known prediction of Einstein's GRT is the deflection (curving) of the light pathway when passing next to a massive cosmic object of M mass. Further on, we shall determine the deflection of the light pathway under gravito-elastic assumptions . According to Fig. 4, an observer found at the distance-D from the cosmic object shall perceive a light deviation angle due to the elastic deformation of the world line (the geodesic is curved and gets close to the object-M). According to the geometry from the drawing and taking into account that for the tandem Sun-Earth: $\Delta r \ll r \ll D$ the deflection angle measured on Earth shall be:

$$sin(\Delta\alpha) = sin(\alpha_0 - \alpha_1) \simeq \frac{\Delta r}{\sqrt{D^2-(r-\Delta r)^2}} \simeq \frac{\Delta \mathrm{r}}{D} \quad (37)$$

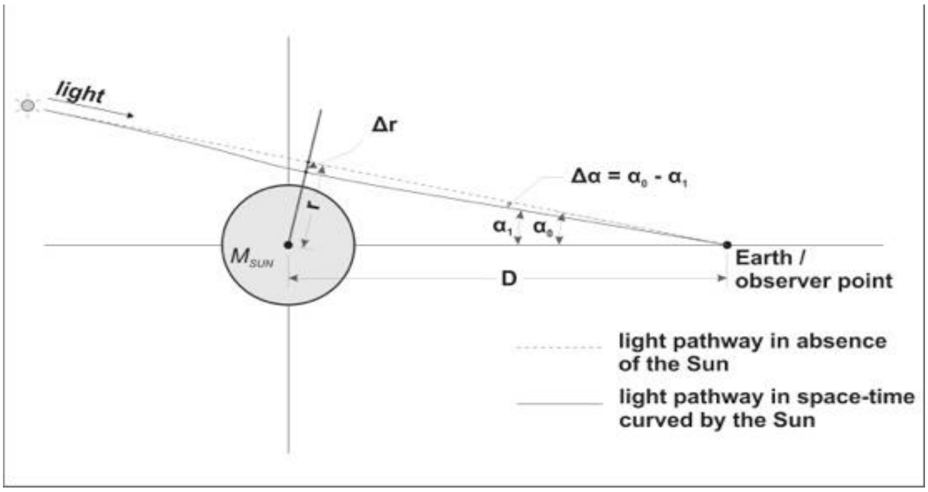

Fig. 4 . The Starlight pathway curved by the Sun

where, $\Delta \boldsymbol{r}$ -shall be computed according to the formula (27). We will evaluate the deflection angle for the: D$\simeq$ $\mathbf{15 \cdot 10^{10} m}$ -the distance from the Sun to the observer (Earth); r $\simeq$ $\boldsymbol{7 \cdot 10^8 m}$ -the Sun radius (the place where the deflection takes place). Using **Observation** from **2.3** we can neglect the ratio ($\frac{\boldsymbol{2r_S^3}}{\boldsymbol{3r^3}}$) in (27) and obtain: $\boldsymbol{\Delta r_{sun}} \simeq \sqrt{\frac{\boldsymbol{2r_S \cdot r}}{\boldsymbol{3}}} = \mathbf{1.18 \cdot 10^6} \boldsymbol{m}$;

Using-(37), finally : $\boldsymbol{sin(\Delta\alpha)} \simeq \frac{\mathbf{\Delta r}}{\boldsymbol{D}}$ **and** $\boldsymbol{\Delta\alpha = arcsin\left(\frac{\Delta r}{D}\right) = 1.63''}$ (38)

By comparison, the value obtained in Cosmology ([1], [3]) is: $\boldsymbol{\Delta\alpha = 1.72''}$.The difference between the 2 values is sufficiently small, since we consider the approximation of the measures used (Sun radius, Sun mass, Sun-Earth distance etc.) and also the geometrical approximation (37) in Fig 4.

2.5 The accelerated expansion of the Universe. The Schwarzschild radius of the Universe

In 2.2 we were talking about the nature of the gravito-elastic force-(28) to increase with distance; this is precisely the one explaining the Accelerated Expansion of the Universe and after that we shall see how Hubble's Law explains this. Therefore, if we will approximate the matter of the Universe as a homogeneous mass body=$\boldsymbol{M_U}$ it shall gravitation-symmetric contract the Space-time "around" it. But, according to (28) the Space-time shall "oppose" this gravitational compression exercised by the matter in the Universe with a force-which, in turn, shall *EXPAND* with acceleration the Vacuum (the Space-time) still available! Basically, we may compute actually the average expansion acceleration of the Space-time from the balance equation of the 2 forces :

$$\overrightarrow{\boldsymbol{F_{GRAVIT}}} = \boldsymbol{M_U} \cdot \overrightarrow{\boldsymbol{a_U}} \equiv \overrightarrow{-\boldsymbol{F_{ELST}}} = \boldsymbol{K_\Omega} \cdot \overrightarrow{\boldsymbol{\Delta r}} \tag{38}$$

Because the Universe is homogeneous and isotropic, the equation (39) is valid omnidirectional, therefore the vector sign $\longrightarrow$ can be neglected:

$$a_U = \frac{K_\Omega \cdot \Delta r}{M_U} = \frac{K_\Omega \cdot \sqrt{\frac{2R_{SU}^3}{3} \Big/ R_U + \frac{2R_{SU}}{3} \cdot R_U}}{M_U} = \frac{Y_0 \frac{4\pi(2R_U)^2}{2R_U} \sqrt{\frac{R_U^2}{6\pi}\left(1+\frac{1}{(4\pi)^2}\right)}}{\frac{4\pi R_U^3}{3}\rho_0} = \sqrt{\frac{6}{\pi}} \frac{c^2}{R_U} > 0 \tag{40}$$

where in (40) we have taken into the measures which characterize the elasticity of the Vacuum (the relations (1), (2) and (3)) and we also used the relation-(10) for M_U-mass to compute the Schwarzschild radius of the Universe defined as follows:

$$R_{SU} \stackrel{\text{def}}{=} \frac{2GM_U}{c^2} = \frac{2G \cdot \frac{R_U}{c^2 \cdot \chi}}{c^2} = \frac{R_U}{4\pi} \tag{41}$$

By introducing in (40) the value that today is known for the radius of the Universe $R_U = 4.2 \cdot 10^{26} m$ we obtain :

$$a_U \simeq 3 \cdot 10^{-10} \frac{m}{s^2}. \tag{42}$$

Therefore, in (42) we have the value computed today for the average expansion acceleration of the Universal Space-time in the gravito-elastic vision. It is interesting that the expansion acceleration of the Universe $\overrightarrow{a_U}$ is inversely proportional with the radius of the Universe (according to (40)) which agrees to the theory of initial Big-Bang explosion: when $R_U \longrightarrow 0$ the initial acceleration $a_U \longrightarrow \infty$ but also with the Theory of the inflationary Universe GUT). **In conclusion, the accelerated expansion of the Universe could be caused by the nature of the gravity-elastic force -(28) which increases by increasing the distance-r and is a counter-reaction to the gravitational contraction trend exercised by the matter in the Universe on the Space-time.** We also notice in (40) that it $\overrightarrow{a_U}$ decreases by increasing R_U, or, in other words, from the Big bang onward, the expansion ratio has continuously decreased and, probably, there shall be a moment of stopping the Universe's expansion. In the case of a certain galaxy containing, let's say, the matter-M homogeneously distributed, it shall gravitationally contract the Space-time towards itself and in compensation to the elastic trend of the “free” Space-time around is to expand with acceleration and as fast as the distance to the -M mass galaxy increases. Taking into account the **Observation** from **2.3** , the elastic expansion force (28) of the Space-time between 2 galaxies becomes

$$\overrightarrow{F_{ELST}} = K_{\Omega} \cdot \overrightarrow{\Delta r} \simeq \sqrt{\frac{2R_S}{3} r} = \sqrt{\frac{2R_S}{3} D_{galaxy}} \sim \sqrt{D_{galaxy}} \qquad (43)$$

therefore it increases by increasing the distance between the 2 galaxies-, in perfect agreement with Hubble’s Law! That is way galaxies seem to distance one from another Fig 5, because, in fact, the space between them is the one which dilates with acceleration under the influence of the gravito-elastic force (43).

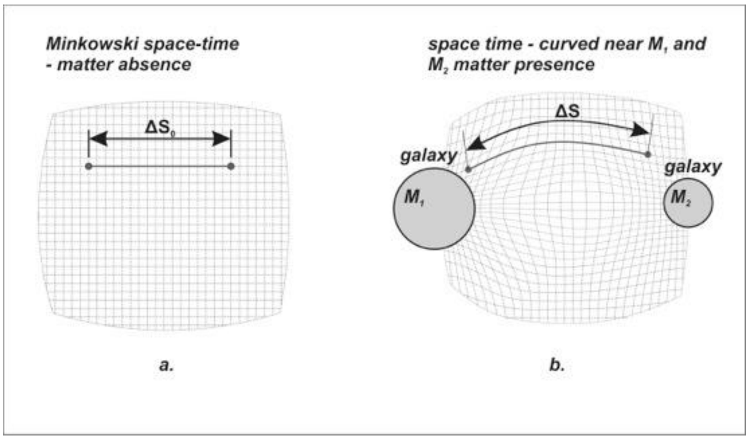

Fig. 5 **.** How increase a Cosmic distance (as like a balloon’s surface) : comparison between Minkowski flat-space-time (a) and curved space-time in matter’s presence (b)

Hence , the elastic response of space-time to the gravitational contraction tendency could be “hidden spring” that generates the Universe’s expansion . As an intuitive analogy: the Universal Space-time behaves like the spherical surface of a balloon which, if compressed on one side, responds by expansion in the free side. This may be the consequence of a “ Space-time Conservation Law” which could be a generalization of the Energy Conservation Law .

3. Conclusions

In the article were studied a few fundamental aspects for Cosmology from the perspective of Space-time’s Elasticity Theory :

- in **2.1** it was calculated the (10)-value of $\boldsymbol{M_U}$-the Universe mass in according with that accepted in the modern Cosmology and more the (3)-value obtained for the light-speed-**c** ; once again they justified choosing formulas-(1)+(2) for the elastic space-time's features.

- in **2.1** it was calculated the Hubble constant-(19) and obtained for exactly the official value accepted today H==$0.25 \cdot 10^{-17} sec^{-1}$ [1].

- in **2.1** it was deducted the equations of the scale factor dynamic, (20) and (21) these are the equivalents of Friedmann equations of GRT, and (21) it is identical to the result obtained in the Friedmann equation (according to [1] and [3]).

- in **2.2** it was determined the gravito-elasticity equation-(24) , the expression of the elastic deformation (27) of the Space-time but also the force expression (28) with which the Space-time opposes to this deformation.

- in **2.3** we have computed the temporal dilatation gravitationally-elastic induced to a standard clock (34) and compared it to the one predicted in Cosmology for the case of the Sun (36) [1].

- in **2.4** we have computed the light deflection angle due to Sun gravity (38) with a value of 1.63'' very close to the one of Cosmology - 1.72" [3].

- in **2.5 contains the main result of this article: an explanation of the accelerated expansion of the Universe and Hubble's Law caused by the nature of the gravito-elastic force (28) to increase with increasing of the distance-(43) and also computed the average expansion acceleration of the Universe (40)- a formula fully agreeing with the Big-Bang Theory and GUT.**

We consider that the gravito-elastic principles studied here open new and interesting perspectives in Cosmology and astrophysics expanding on the knowledge gains so far through GRT alone. These principles may assist in the consequent understanding of gravitational waves, Big-Bang or quantum gravity.

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