The Friedmann equations and inflationary cosmology in the effect of gravity hypothesis

Adrián G. Cornejo
Electronics and Communications Engineering from Universidad Iberoamericana, Calle Santa Rosa 719, C. P. 76138, Col. Santa Mónica, Querétaro, Querétaro, México.

E-mail: adriang.cornejo@gmail.com

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Abstract

The proposed effect of gravity hypothesis considers that gravity can be explained by the inertial effect that results of combine both, curvature of space-time and its accelerated expansion as a non-inertial frame of reference, deriving an approximate equivalent to the so-called "concise form of Einstein's field equation", but where "field of gravity" concept is not involved. On this hypothetical scenario, corresponding non-relativistic expressions analogous to the Friedmann equations and inflationary cosmology are described.

Keywords: Einstein's field equation, Non-inertial frame of reference, Friedmann equations, Inflationary universe.

Resumen

La hipótesis propuesta del efecto de gravedad considera que la gravedad puede explicarse por el efecto inercial que resulta de combinar la curvatura del espacio-tiempo y su expansión acelerada como un sistema de referencia no-inercial, derivando una equivalencia aproximada a la llamada "forma concisa de las ecuaciones de campo de Einstein", pero donde el "campo de gravedad" no está involucrado. Bajo este escenario hipotético, son descritas las correspondientes expresiones no relativistas análogas a las ecuaciones de Friedmann y la cosmología inflacionaria.

Palabras clave: Ecuación de campo de Einstein, marco de referencia no-inercial, ecuaciones de Friedmann, universo inflacionario.

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I. INTRODUCTION

Gravitation is considered one of the four fundamental interactions of nature, together with the electromagnetism, weak interaction and strong interaction [1]. As background, gravity was described in 1687 by Newton as the force exerted by a central force acting upon point masses around it [2], as the dynamics of a body orbiting around a massive body.

Thus, although most orbits are elliptical in nature, a special case is the circular orbit, considered as an ellipse of zero eccentricity. This consideration simplifies the calculations to the case of circular orbit. Formula for velocity of a given body in a circular orbit around a central mass [3] is given by

$$v_o^2 = \frac{GM}{r}, \quad (1)$$

where v_o is the orbital velocity of body, being G the Newtonian constant of gravitation, M the mass of a massive body (as that of the Sun) and r is the distance from the center of mass where M exists. Applying equivalence with the accelerated circular motion, hence

$$v_o^2 r = ar^2 = GM \therefore a = \frac{GM}{r^2}, \quad (2)$$

where a is the acceleration of the given body. According to the Newton's second law, undergone force is defined as the mass m of given body by its acceleration, given by:

$$F = \frac{d}{dt}(mv_o) = ma = \frac{GMm}{r^2}. \quad (3)$$

According to this formulation, GM is dependent of the acceleration and geometrically related to the inverse of the square of the distance.

Later, in 1796 Laplace attempted to model gravity as some kind of radiation field or fluid [4]. Thus, since the 19th century, gravity has been usually explained in terms of a "field model", rather than undergone forces by the bodies as result of the experienced impulse given by the acceleration of their masses, in accordance to the Newton's second law.

Einstein's General Theory of Relativity (GTR) [5] also considers gravity due to a gravitational field which causes attractive forces between the bodies, where that field is determined as the solution of Einstein's field equations.

These equations are dependent on the distribution of matter and energy in a region of space (described by the stress-energy tensor), unlike Newtonian gravity, which is dependent only on the distribution of matter (described by the quantity of matter in a given volume).

Curvature of space-time is one of the main consequences of GTR, which states that gravity is the effect or consequence of the curved geometry of space-time. GTR deducts the equivalence principle (introduced by Einstein in 1907) [6] assumes the complete physical equivalence of a gravitational field and a corresponding accelerated frame of reference.

From this principle, Einstein concluded that free-fall is actually inertial motion. In this way, gravitational "force" as experienced locally while standing on a massive body is actually the same as the non-inertial (also called pseudo-force) experienced by an observer in a non-inertial (accelerated) frame of reference.

On the other hand, in 1922 Alexander Friedmann derived his Friedmann equations [7] by inserting the metric for a homogeneous and isotropic universe into Einstein's field equations for a fluid with a given density and pressure, showing that the universe might expand at a rate calculable by the equations (Georges Lemaître independently found a similar solution in 1927). This idea of an expanding universe would eventually lead to the Big Bang model.

In 1929 Edwin Hubble from previous and his own observations of distant galaxies where redshift increases with distance deducted the expansion of the universe [8]. The observed velocity of distant galaxies, taken together with the Einstein's cosmological principle [9] (homogeneity and isotropy structure of the universe), was the first observational support for the Big Bang model from which is considered that time and the universe began from the Big Bang (when time equals zero) [10]. According to the observations of the Supernova Legacy Survey (SNLS) [11], it is considered that the universe is currently in accelerated expansion [12].

Furthermore, in 1959 Robert H. Dike first proposed to make a distinction between the wake and the strong equivalence principle (SEP) [13] which suggests that gravitation has a nature purely geometric (it means that the metric defines the effects of the gravity) and it does not contain any field associated with it. In such a concept, the fields themselves would represent the curvature of space-time. Nevertheless, nature of gravity has not been enough clarified and some theories and hypothesis have been developed to explain its nature.

A previous work [14] considers a hypothetical scenario where gravity results as an inertial effect of combine both, curvature of space-time (for instance, as a spherical surface distorted by the high concentration of matter, as proposed by Einstein) [5] and its acceleration from a central origin as a non-inertial frame of reference that follows the accelerated expansion of the universe. Relating escape velocity when it tends to the speed of light results an equivalent expression to the so-called "concise form of Einstein's field equation", but it derived from an inertial effect where "field of gravity" is not involved. In this scenario, action-at-a-distance for gravity is not due to any kind of localized field, but is present when one or more bodies share a given common region on a spherical surface in accelerated dilation, and its distortion (if any) deflects the moving bodies, resulting in a different movement of them that is perceived as a "direct interaction" [15]. Here is shown that geometry and dynamics of such a scenario is also consistent with the Friedmann equations and Inflationary cosmology theory.

II. THE NON-INERTIAL FRAME IN RADIAL ACCELERATION AND THE EFFECT OF GRAVITY REVISITED

Einstein's equivalence principle considers that a gravitational field is equivalent to an accelerated frame of reference. Here is considered that such an accelerated frame of reference corresponds to the accelerated expansion of the universe. Non-inertial frame of reference is traditionally derived by a coordinate transformation. Thus, in order to derive the undergone effect on a non-inertial frame of reference, let us consider a given body in circular motion with constant velocity v and radius r circumgyrating around a central point O on the x and y axes. Its position vector [16] is given by

$$r' = v_t t, \tag{4}$$

where v_t is the tangential velocity of the given body and t is the time. When such a body in circular motion is also uniformly accelerated towards the vertical direction (it is, along the z-axis), then its position vector is given by

$$r_0 = v_0 t + \tfrac{1}{2} a t^2, \tag{5}$$

where v_0 is the initial velocity of the given body and a is its acceleration along that z-axis. Having that relative velocity is the velocity of a body (or a frame of reference) with respect to other; it is related only in systems of two bodies (or two frames of reference). Thus, for a fixed observer is given by

$$r = r' + r_0 = v_t t + \left(v_0 t + \tfrac{1}{2} a t^2\right), \tag{6}$$

where its components in a three-dimensional frame of reference are given by:

$$\begin{cases} r = v_t t \therefore t = \dfrac{r}{v_t}, \\ z = v_0 t + \tfrac{1}{2} a t^2. \end{cases} \tag{7}$$

Solving (7), equation of its trajectory as it is seen by a fixed observer on the given body, hence:

$$z = v_0\left(\frac{r}{v_t}\right) + \tfrac{1}{2}a\left(\frac{r}{v_t}\right)^2, \qquad (8)$$

which is a parabola. When the acceleration starts from the rest, initial velocity equals zero and expression (8) becomes:

$$z = \frac{ar^2}{2v_t^2}. \qquad (9)$$

We can generalize expression (9) for a spherical scenario extending vertical acceleration from along only one *z*-axis to several radial "*z*-axes" starting all of them from a common central point. Then, in a homogeneous acceleration, a sphere (by simplicity) in accelerated dilation is formed. Equation of the radial motion will be equivalent to the radius *R* of the formed sphere, hence:

$$R = \frac{ar^2}{2v_t^2}. \qquad (10)$$

In order to derive the scalar curvature of a spherical surface in accelerated dilation, we can write expression (10) in terms of the resultant area. Surface of the formed figure can be derived by multiplying expression (10) by $4\pi R$, hence:

$$4\pi R^2 = 4\pi\left(\frac{ar^2}{2v_t^2}\right)^2. \qquad (11)$$

Furthermore, Gaussian curvature of a surface is the real number $K(P_0)$ which measures the intrinsic curvature in each regular point P_0 of such a surface [17]. This Gaussian curvature in general varies from a point to other of the surface and it is related with the main curvatures of each point (k_1 and k_2) through the expression $K = k_1k_2$, where to the spherical surface of radius *r* (2-sphere), Gaussian curvature is the same for all of its points, defined as:

$$K(S^2) = \frac{1}{r^2} > 0. \qquad (12)$$

Thus, finding out the curvature for a given section of the distorted spherical surface from (11) and applying equation (2), yields:

$$\frac{1}{r^2} = \frac{4\pi a^2 r^2}{\left(2v_t^2\right)^2 4\pi R^2} = \frac{4\pi GMa}{\left(2v_t^2\right)^2 4\pi R^2}. \qquad (13)$$

According to the cosmological principle [9], space-time could be considered as a spherical surface (by simplicity) currently in accelerated dilation, where its area in S^3 given by $A = 4\pi R^2$, could be distorted by a massive body *M* that exerts a force *F* per unit area on such a surface while *R* accelerated increases [18]; where for the case of sphere is giving by:

$$T'_{\mu\nu} = \frac{F}{A_{\mu\nu}} = \frac{Ma}{4\pi R^2}, \qquad (14)$$

where $T'_{\mu,\nu}$ is the "stress tensor" and indexes μ,ν run through 1, 2, 3. Expression (14) represents distortion of the spherical surface due to the pressure as force per unit area. Stress tensor could be considered as an approximated equivalent to the stress-energy tensor ($T_{\mu,\nu}$) considered in GTR [19]. Nevertheless, stress tensor is a scalar magnitude and no energy part (by a field) is involved, but the acceleration of the frame of reference acts as source of the dynamics. Thus, substituting stress tensor from expression (14) in expression (13), yields:

$$\frac{1}{r^2} = \frac{4\pi G}{\left(2v_t^2\right)^2}\frac{Ma}{4\pi R^2} = \frac{4\pi G}{\left(2v_t^2\right)^2}T'_{\mu\nu}. \qquad (15)$$

In two dimensions (for a given area), scalar curvature is exactly twice the Gaussian curvature [20]. For an embedded surface in Euclidean space, this means that for expression (15), yields:

$$S = \frac{2}{\rho_1\rho_2} \rightarrow \frac{2}{r^2} = \frac{8\pi G}{\left(2v_t^2\right)^2}T'_{\mu\nu}, \qquad (16)$$

where ρ_1, ρ_2 are the principal radii of the surface. For example, scalar curvature in S^3 of a sphere with radius *r* is equal to $2/r^2$. The 2-dimensional Riemann tensor has only one independent component and it can be expressed in terms of scalar curvature and metric area form. In any coordinate system, one thus has:

$$2R_{1212} = S\det(g_{ij}) = S[g_{11}g_{22} - (g_{12})^2]. \qquad (17)$$

Now considering that each point on the radial *w*-axis that forms the surface has its own *z*-axis (orthogonal to the *x*, *y*-axes), then we can extend expression (16) to a four-dimensional frame of reference in function of (*w*, *x*, *y*, *z*), and expressing it in Riemann tensor terms (applying tensor Einstein's notation), hence:

$$S^4 = \frac{8\pi G}{\left(2v_t^2\right)^2}T'_{\mu\nu}, \qquad (18)$$

where indexes μ,ν run through 1, 2, 3, 4. Expression (18) extended to a four-dimensional frame of reference is related by the tangential velocity of the given body. Nevertheless, we can attempt to derive an approximation to the relativistic expression related by the speed of light [5] by considering a given body orbiting around a center of mass [21], where radius from the center of mass is tending to the Schwarzschild radius [22] (approximately of 2.95 Km for the Sun). Equivalence between orbital velocity and escape velocity [23], where escape velocity is tending to the speed of light is given by:

$$v_e^2 = 2v_t^2 = v_o^2\left(\frac{2r_o}{r_e}\right) \to c^2 = v_o^2\left(\frac{2r_o}{r_S}\right), \qquad (19)$$

where r_o is the distance from the center of mass, being r_e the escape radius, r_S is the Schwarzschild radius, v_o is the orbital velocity, v_e is the escape velocity and c is the speed of light in vacuum. Then, replacing expression (19) in (18), we can write as:

$$S^4 = \frac{8\pi G}{\left[v_o^2\left(\frac{2r_o}{r_S}\right)\right]^2} T'_{\mu\nu}, \qquad (20)$$

where indexes μ,ν run through 1, 2, 3, 4. Expression (20) describes scalar curvature of a spherical surface in accelerated dilation when is distorted by the presence of high concentration of matter on such a surface, related by the orbital velocity of a given body along the curvature of space-time in accelerated dilation. Thus, the body should undergo an "induced" motion by the deviation along the distorted surface experiencing as inertial force acting upon the given body (which could apparent an attractive force between the bodies). Replacing speed of light from expressions (19) in expression (18), hence:

$$G_{\mu\nu} \approx S^4 = \frac{8\pi G}{c^4} T'_{\mu\nu}, \qquad (21)$$

where $G_{\mu\nu}$ is the Einstein's tensor and indexes μ,ν run through 1, 2, 3, 4. This is an equivalent expression to the so-called "concise form of Einstein's field equation" [5, 9], but it derived from a non-relativistic way which does not consider energy from a "field of gravity".

In the same way, from the equivalences (2) and (19), equivalence of expression (10) is defined as:

$$R = \frac{ar^2}{2v_t^2} = \frac{ar^2}{v_e^2} \to R = \frac{GM}{c^2}, \qquad (22)$$

which is a non-relativistic expression equivalent to the Schwarzschild metric [23]. Applying equivalence between matter and density of matter ($m = Vol\rho$) in equation (13), for the spherical surface, yields:

$$\frac{2}{r^2} = \frac{8\pi G}{c^4}\frac{Ma}{4\pi r^2} = \frac{8\pi G}{c^4}\frac{\left(\frac{4}{3}\pi r^3\right)\rho a}{4\pi r^2} = \frac{8\pi G}{3c^2}\rho. \qquad (23)$$

III. THE FRIEDMANN EQUATIONS AND THE DYNAMICS OF THE UNIVERSE

In the early twentieth century, redshift of some galaxies was discovered, being associated to the Doppler effect for light [24]. Doppler effect describes the change in frequency of a wave for an observer moving relative to the wave source [25]. Redshift happens when light or other electromagnetic radiation from an object is increased in wavelength, which can be done due to the motion of the light source with respect to other objects. Based on wavelength, redshift is defined as:

$$z = \frac{\lambda_r - \lambda_e}{\lambda_e}, \qquad (24)$$

where z is the redshift, λ_r is the wavelength of the receiver relative to the medium; positive if the receiver is moving towards the source (and negative in the other direction) and λ_e is the wavelength of the emitter.

Discovery of the linear relationship between redshift and distance, coupled with a supposed linear relationship between recessional velocity and redshift, allowed Hubble to combine his measurements of galaxy distances with the previous measurements of the redshifts associated with the galaxies, proposing a rough proportionality between redshift of an object and its distance [9], given by:

$$\frac{\lambda_r}{\lambda_e} = z + 1 = \frac{v_e}{c} + 1 \to z = \frac{v_e}{c}, \qquad (25)$$

and then,

$$z = \frac{\lambda_r - \lambda_e}{\lambda_e} = \frac{v}{c} = \frac{H_0}{c}D, \qquad (26)$$

where v is the recessional velocity ($v = dD/dt$), H_0 is Hubble's constant and corresponds to the value of H for the present (often termed the Hubble parameter which is a value that is time dependent, being the reciprocal of H_0 the Hubble time), D is the proper distance from the galaxy to the observer, measured in mega parsecs (Mpc), and c is the speed of light. Thus, Hubble's Law is defined as:

$$v = H_0 D. \qquad (27)$$

Considering the proper velocity (called peculiar velocity) of a galaxy through the space by the effect of gravity, then the velocity-distance relation is written as:

$$v = HD + V. \qquad (28)$$

Value of H can be calculated by:

$$H_0 = h\frac{10^7\, cm/s}{3.0856\times 10^{24}\, cm}, \qquad (29)$$

where $h = H_0/100$.

The parameter used by Friedmann is known as the scale factor which can be considered as a scale invariant form of the proportionality constant of Hubble's Law. In the Friedmann equations, redshift is defined as:

$$z = \frac{a_{now}}{a_{then}} - 1, \qquad (30)$$

where a_{now} is the scale factor for now and a_{then} is the scale factor for then, and $R(t)$ is the "radius" of the universe, or more precisely, its scale factor. Then, relationship with the Hubble's constant is given by:

$$\frac{dR}{dt} \propto R \rightarrow \dot{R} = HR \therefore H = \frac{\dot{R}}{R}, \qquad (31)$$

$$R(t) = a(t)x \therefore x = \frac{R(t)}{a(t)}, \qquad (32)$$

being the Hubble's constant given by:

$$H = \frac{\dot{R}}{R} = \frac{\dot{a}}{a}. \qquad (33)$$

Furthermore, dynamics and geometry described by the Friedmann equations are "compatible" with the solution given by the classical mechanics to describe dynamics of a homogeneous and isotropic spherical surface in accelerated dilation. Then, total energy of the system is given by:

$$E = E_c + E_p, \qquad (34)$$

where E_c is kinetic energy and E_p is potential energy. For a gravitational system, total energy of the system is given as:

$$E = \tfrac{1}{2}mv^2 - \frac{GMm}{R}. \qquad (35)$$

Applying equivalence between matter and density of matter (multiplied by volume), for a spherical surface, yields:

$$E = \tfrac{1}{2}mv^2 - \frac{Gm\left(\tfrac{4}{3}\pi R^3\right)}{R}\rho. \qquad (36)$$

Then, multiplying (36) by $2/mR^2$ and reordering, hence:

$$\frac{2E}{mR^2} = \frac{v^2}{R^2} - \frac{8\pi G}{3}\rho. \qquad (37)$$

Furthermore, in a homogeneous and isotropic spherical surface, according to (12), curvature is given by:

$$K = \frac{1}{x^2}, \qquad (38)$$

where K is the Gaussian curvature. Multiplying this expression by $2mv^2$, yields:

$$K = \frac{1}{x^2}\frac{2mv^2}{2mv^2} = -\frac{1}{x^2}\frac{2E}{mv^2}, \qquad (39)$$

where sign is negative by convenience.

Rewriting and considering that velocity is tending to the speed of light, hence:

$$\frac{Kc^2x^2}{R^2} = -\frac{2E}{mR^2}. \qquad (40)$$

Replacing (40) in (37), yields:

$$-\frac{Kc^2x^2}{R^2} = \frac{v^2}{R^2} - \frac{8\pi G}{3}\rho, \qquad (41)$$

and according to the expression (32), we can write as:

$$H^2 = \frac{\dot{a}^2}{a^2} = \frac{8\pi G}{3}\rho - \frac{Kc^2}{a^2}, \qquad (42)$$

and for acceleration, hence:

$$\frac{\dot{a}^2}{a^2} = \frac{1}{a}\left(\frac{\dot{a}^2}{a}\right) = \frac{\ddot{a}}{a} = -\frac{8\pi G}{3}\rho = -\frac{4\pi G}{3}(\rho + \rho), \qquad (43)$$

where sign is negative by convenience, which comes from the derivative of ρ, given by $d\rho/dt = -3H(\rho + p)$.

Equivalence of density of matter and pressure [26] according to (14) is given by:

$$p = \frac{F}{A} = \frac{Ma}{4\pi R^2} = \frac{aR\rho}{3} \therefore \rho = \frac{3p}{c^2}, \qquad (44)$$

where p denotes the pressure. Replacing ρ in one of the terms of (43), yields:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right). \qquad (45)$$

Equations (42) and (45) are non-relativistic expressions analogous to the Friedmann equations without a cosmological constant. In the Friedmann equations, geometry of the universe also depends of the curvature, where K = +1 for a closed universe, −1 for an open universe, or 0 for a flat Friedmann universe.

Thus, regardless of the model used ($K = \pm 1, 0$), the scale factor vanishes at some time $t = 0$, and the matter density at that time becomes infinite. It can also be shown that at that time, the curvature tensor $R_{\mu\nu}$ goes to infinity as well. That is why the point $t = 0$ is known as the point of the initial cosmological singularity (Big Bang).

In a closed universe with $p > -\rho/3$, there will be some point in the expansion when the term $1/a^2$ in (42) becomes equal to $8\pi G/\rho$. Thereafter, the scale constant a decreases, and it vanishes at some time t_c (Big Crunch) [27]. On the other hand, an open or flat universe will continue to expand forever.

An expression for the critical density is found from the Friedmann equations by assuming cosmological constant to be zero (as it is for all basic Friedmann universes) and setting the normalized spatial curvature, K, equal to zero. This consideration simplifies the calculations. When the substitutions are applied to the first of the Friedmann equations (42), yields

$$\rho_c = \frac{3H^2}{8\pi G}, \tag{46}$$

where ρ_c is the critical density. In addition, the density parameter Ω is defined as the ratio of the actual (or observed) density to the critical density of the Friedmann universe. The ratio of the actual density of the universe to the critical density (useful for comparing different cosmological models) is given by the quantity:

$$\Omega = \frac{\rho}{\rho_c} = \frac{8\pi G}{3H^2}\rho. \tag{47}$$

Evolution of the scale factor $a(t)$ for three different versions of the Friedmann hot universe theory can be closed, open or flat. The relation between the actual density and the critical density determines the overall geometry of the universe.

When Ω is larger than unity, the space sections of the universe are closed and the universe will eventually stop expanding, and then collapse. When Ω is less than unity, they are open and the universe expands forever. The observational data imply that $\Omega = 1.01 \pm 0.02$ [27].

IV. INFLATIONARY COSMOLOGY AND THE DENSITY OF MATTER

In 1980 Alan Guth proposed that the universe could drive cosmic inflation in the very early universe [28], resulted in an enormous and exponential expansion of the universe slightly after the Big Bang. This expansion is an essential feature of most current models of the Big Bang, providing a solution to the horizon and flatness problems.

Considering that the universe began its expansion in the vacuum then density for vacuum ρ_v is constant in the beginning, and Friedmann equation (42) becomes:

$$H^2 = \left(\frac{dR/dt}{R}\right)^2 = \frac{8\pi G}{3}\rho_v \rightarrow const. \tag{48}$$

Having the property of e, given by:

$$\frac{d}{dx}e^x = e^x, \tag{49}$$

we can write as:

$$\frac{dR}{dt} \propto R \rightarrow R(t) \propto e^{Ht}, \tag{50}$$

and then:

$$R(t) = const \times e^{\sqrt{\frac{8\pi G}{3}\rho_v}\,t}. \tag{51}$$

This analogous equation to the Inflationary cosmology has an exponential growing with H as constant which means inflation in the period while ρ_v remained constant. The inflationary period finished when the quantity of matter density changed.

V. CONCLUSIONS

This paper follows the hypothetical alternative physical explanation for a celebrated effect, the gravity (which is not merely a reformulation of the previous knowledge).

Nevertheless, this hypothesis is based on an inertial effect which is explained by the classical mechanics and also considers some deductions from the main theories about gravity, as curvature of space-time and the equivalence principle regarding to the comparison of gravity and a non-inertial frame of reference, which are considered in GTR.

Then, gravity is related with the curvature of space-time (for instance, distorted by a massive body) and its considered accelerated expansion, where both together would contribute to produce an inertial effect experienced as a motion due to the inertial force (which could be undergone like the effect of gravity) by a given body looking for the equilibrium on the curved surface in accelerated dilation.

An approximated equivalent expression with the "concise form of Einstein's field equation" is derived mainly from classical mechanics concepts by consider space-time as a non-inertial frame of reference, where derived "stress tensor" is also an approximated equivalent with the stress-energy tensor of GTR, but those without the concept of mutual attractive forces of gravity exerted as a "field of gravity" to produce effect of gravity.

This scenario is also applied to derive the Friedmann equations without a cosmological constant, being consistent with the known predictions about evolution of the universe and Inflationary cosmology theory.

Regarding to the education, main Newtonian and relativistic concepts and main principles for gravity are revisited. It is showed the possibility to apply the current knowledge in order to propose alternative explanations of the observed natural phenomena. As a possible interpretation, we represent space-time as a dynamics surface in accelerated dilation capable to be distorted by high concentrations of matter, in order to apply classical concepts also to attempt explain some effects of nature that are traditionally explained by the relativistic theories.

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