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GENERAL FEATURES AND PERSPECTIVES OF A-TEMPORAL GRAVITATION THEORY

Davide Fiscaletti,
SpaceLife Institute, San Lorenzo in Campo (PU), Italy
fiscalettidavide@libero.it

Abstract

Space-time is a math model into which one describes motion of massive bodies and particles in space. There is no experimental evidence about space-time existing as a physical reality. With clocks one does not measure time, one measures duration of movement of bodies and particles in space. Time exists only as a material change (movement) of bodies and particles in space. Time does not run into space on its own, space itself is a-temporal.

A-temporal physical space is the "stage" (arena) in which stellar objects and elementary particles move. An a-temporal interpretation of gravitational interaction, both inside the classical scheme and from the general relativistic point of view, is proposed. According to classical a-temporal gravitation, gravitational force is transmitted by the density of a-temporal physical space: the material objects move in the direction where the density of cosmic space is increasing. Moreover, the idea of an a-temporal space-gravity endowed with wave nature is proposed, in which the appearance of mass can be seen as an effect of resonance. According to an a-temporal interpretation of general relativity, gravity is transmitted by the density tensor of physical space and its effect is to curve this a-temporal space. All the typical effects of general relativity are linked to the density of a-temporal cosmic space.

Finally, a new interpretation of Mach's principle is shown, in which the density of cosmic space is the fundamental element. Also this principle provides an important clue toward the idea of a radical timelessness in space.

1. Introduction

On the basis of elementary perception, the passing of the time cannot be perceived directly as matter and space; we can perceive only the changes of matter in space. Time cannot be considered a "real" physical entity, it exists only as a stream of material changes happening in an a-temporal space. It is fundamental to understand that change does not run in time, change itself is time. Time means change (movement) and, therefore, when there is no change there is no time. Clocks run in a-temporal space. With clocks we measure the duration and the numerical order of all changes. We are born, we live and we die in the same identical a-temporal space [1].

Phenomena run in space-time only in the mathematical models of reality, which sometimes become more real than reality itself, which instead – on the ground of our elementary perception – turns out to be a-temporal. The stage in which natural phenomena happen is not space-time but is an a-temporal space. This is an alternative, different point of view from that conventionally adopted in physics, but is perhaps more correct and appropriate because is more coherent with experimental facts (i.e. with the fact that there is no evidence that material objects move in time) [2, 3].

On the other hand, different physical theories treat space as a quantum. In particular, loop quantum gravity suggests that at the most fundamental level physical space has a granular structure, namely is composed by elementary grains, a net of intersecting loops, having the Planck size [4, 5]. Since the quantum numbers of these elementary grains and their algebra look like the spin angular momentum numbers of elementary particles, the elementary grains of space, i.e. the loops of the net, can be appropriately defined spin elements or "spin networks". According to loop quantum gravity nodes of spin networks represent the elementary grains of space, and their volume is given by a quantum number that is associated with the node in units of the elementary Planck volume, $V = (\eta G / c^3)^{3/2}$, where η is Planck's reduced-constant, *G* the universal gravitation constant and *c* the speed of light. Two nodes are adjacent if there is a link between the two, in which case they are separated by an elementary surface the area of which is determined by the quantum number associated with that link. Link quantum numbers, j , are integers or half-integers and the area of the elementary surface is $A = 16\pi V^{2/3}\sqrt{j(j+1)}$, where *V* is the Planck volume.

Taking into account the results of loop quantum gravity, if one assumes that space-time is really a four-dimensional a-temporal space (in which the fourth coordinate indicates the numerical order of material movements), it turns out to be permissible to assume that this a-temporal space has a granular structure at Planck scale. In other words, it turns out to be permissible to assume that quanta of space having the size of Planck length $l_p = \sqrt{\frac{\eta G}{c^3}}$ are the fundamental constituents of space (namely that it is not possible to observe areas or volumes smaller than Planck scale) and that Planck time $t_p = \sqrt{\frac{\eta G}{c^5}}$ is the least unit of motion (namely that it is not possible to observe numerical order of movements smaller than Planck time).

Starting from the idea that space has a granular structure and is a-temporal, interesting perspectives are opened in theoretical physics. In particular, in quantized a-temporal physical space the fundamental interactions and physical fields can be interpreted as the special states of space under determinate situations, can be seen as entities which derive from real properties of space [6].

2. A new view of gravitation inside the classical scheme

If time exists only as a stream of irreversible material changes happening in space, a new interpretation of gravitational interaction emerges: the a-temporal gravitation theory. In this model, gravitational interaction is carried directly by the density of cosmic space, has not speed and is a-temporal (in the sense that no movement of particle-wave is needed for its acting).

According to a-temporal gravitation theory, space has granular structure, namely is composed by quanta of space (QS) having the size of Planck length $l_p = \sqrt{\frac{\eta G}{c^3}}$ and gravitational interaction is immediate, acts instantly through the density of cosmic space. Gravity is transmitted by the density of cosmic space existing in each quantum of space. The density of cosmic space is the fundamental physical property which describes universal space. It depends on the amount of matter present in the region under consideration. The density of cosmic space associated with a material object of mass *m* in the QS situated at distance *r* from the centre of this object is defined by the relation $D(r) = \frac{Gm}{r^2}$ (1) where *G* is gravitational constant. In particular, for $r = l_p$, where $r = l_p$ is Planck length, we obtain the density of cosmic space existing in the centre of the material object: $D(l_p)=\frac{Gm}{l_p^2}$ (2). The density of cosmic space existing in the centre of a material object is not infinite but is given by (2) because according to this model space is not indefinitely divisible, but has a minimal size which coincides just with Planck length.

While in the classical, Newtonian vision, the source of gravitational field is mass, in this model we suggest the idea that the gravitational field in each point of space is a property that depends on the density of cosmic space existing in that point. It is the density of cosmic space that determines the appearance of a gravitational field in each point of space. In our view, gravity is determined by the density of cosmic space and the density of cosmic space, on the basis of equation (1), is a property which characterizes all the points of the universal space. We can deduce therefore that gravity itself can be considered a property characterizing all the points of the universal space thus depending on the density of cosmic space. Introducing the concept of density of cosmic space given by relation (1), the gravitational field existing in the QS situated at distance *r* from the centre of a given material object of mass *m* assumes the form $\vec{g}=D(r)\hat{r}$ (3) namely derives directly from the density of cosmic space into consideration.

The extension to the case of more material objects is immediate. If in a region of space there are n material objects of mass m_1, m_2, …, m_n, the gravitational field existing in a given point P (situated at distance r_1 from the centre of the first material object of mass m_1, at distance r_2 from the centre of the material object of mass m_2, …, and at distance r_n from the centre of the material object of mass m_n) is given by the relation $\vec{g}_{tot}(P)=\vec{g}_1(P)+\vec{g}_2(P)+...+\vec{g}_n(P)=D_1(r_1)\hat{r}_1+D_2(r_2)\hat{r}_2+...+D_n(r_n)\hat{r}_n=D_{tot}(P)\frac{\hat{r}_1+\hat{r}_2+...+\hat{r}_n}{\sqrt{n}}$ where $D_1(r_1)$ is the density of cosmic space characterizing the point P and associated with the first material object of mass m_1, $D_2(r_2)$ is the density of cosmic space characterizing the point P and linked to the second material object of mass m_2, and so on (4).

Newton's gravitational attraction between two masses m_1 and m_2 (situated at distance *r*) can be seen as a consequence of a more fundamental attraction of QS characterized by a different density of cosmic space. In fact, if $D_1(r_1)=\frac{Gm_1}{r_1^2}$ is the density of cosmic space associated with a material object of mass m_1 in a given quantum of space situated at distance r_1 from its centre, $D_2(r_2)=\frac{Gm_2}{r_2^2}$ is the density of cosmic space associated with a material object of mass m_2 in a given quantum of space situated at distance r_2 from its centre, *r* is the distance between these two particular QS, we can write: $\vec{F}_g=\frac{D_1(r_1)\cdot D_2(r_2)\cdot r_1^2\cdot r_2^2}{Gr^2}\hat{r}$ (5) which represents the general law of interaction between two density of cosmic space (the one associated with the mass m_1, the other associated with the mass m_2). If we take $r_1=l_p$ and $r_2=l_p$, equation (5) becomes $\vec{F}_g=\frac{D_1(l_p)\cdot D_2(l_p)\cdot l_p^4}{Gr^2}\hat{r}$ (6) which represents the law of interaction between the densities of cosmic space characterizing, respectively, the centres of the two objects of mass m_1 and m_2. Taking into account the definition of the density of cosmic space in the centre of a material object, namely that $D_1(l_p)=\frac{Gm_1}{l_p^{\,2}}$ and $D_2(l_p)=\frac{Gm_2}{l_p^{\,2}}$, equation (6) becomes $\vec{F}_g = G\frac{m_1 \cdot m_2}{r^2}\hat{r}$ (7) which is Newton's law of gravitational interaction written in the standard form.

We have shown in this way that Newton's law (7) is perfectly equivalent to equation (6) which, in turn, is a particular case of the more general equation (5). We can therefore conclude that, introducing the density of cosmic space, Newton's law (7) can be considered a particular case of a more general equation, the equation (5), which describes the interaction between two densities of cosmic space, the one associated with the mass m_1, the other associated with the mass m_2. A-temporal gravitation theory opens therefore this important perspective in theoretical physics: two QS characterized by different density of cosmic space attracts each other and this concerns all the pairs of QS satisfying this condition. And the following interpretation of masses' interaction derives: the material objects move in the direction where the density of cosmic space is increasing. But, of course, as each quantum of space is characterized by the property of the density of cosmic space, not only the centres of the objects move but also all the other QS move according to equation (5).

In other words, a-temporal physical space can be seen as an elastic medium which has a tendency to shrink. The more medium is dense, the stronger the force of shrinking. The force of shrinking is the gravitational force [7]. According to the model here proposed, areas of lower density have a tendency to move towards the areas of higher density. That is why objects with lower mass have a tendency to move towards objects with bigger mass.

The fundamental ideas of the approach here suggested can be also expressed in the following way. We can say that if a region of space is characterized by a density of cosmic space given by (1) in the QS situated at distance *r* from a given point P, this means that in the region there is a material object of mass *m* and that the point P is the centre of this material object. It is the density of cosmic space (1) that determines the appearance of a material object in a given region of space. In other words, considering a certain region of space, the mass of a particle can be seen as the "portion" of that region where the density of cosmic space is bigger. This view allows us to interpret mass as a quantity which is not much different from space, as a consequence of a property of cosmic space, namely its density.

The generalization to the case in which space is characterized by *n* material objects is immediate. In fact, we can say that, if in a region of space there are n densities of cosmic space $D_1(r_1)$, $D_2(r_2)$, …, $D_n(r_n)$ and in the generic point P there is a gravitational field given by equation (4), this means that in this region there are n material objects. It is the gravitational field (4) tied to n different densities of cosmic space that determines the appearance of n material objects in a given region of space. In other words, considering a certain region of space, the masses of n particles can be seen as the "portions" of that region where each of the n densities of cosmic space characterizing that region assumes its biggest value.

Moreover, it is important to understand that, while in the classic view the gravity in the centre of an object is zero, our model foresees that in the centre of stars and planets the gravitational force is not zero. This is a consequence of the fact that the density of cosmic space existing in the centre of the material objects is the fundamental element that determines the behavior of those objects (the density of cosmic space in the centre of an object is the maximum value of the density of space associated with that object). A given mass *m* situated in the centre of a planet overcomes a gravitational force of modulus given by the relation: $F_g = m \cdot D(l_p)$ (8) where $D(l_p)$ is the density of cosmic space existing in the centre of the planet.

Finally, it is important to underline that the density of cosmic space given by equation (1) predicts a different result from Newton's shell theorem as regards the value of the gravitational acceleration inside a planet or a star. According to Newton formula gravitational acceleration *g* on the point T under the surface of the earth is: $g_T = [(m - \Delta m)G]/(r-d)^2$ (9) where *m* is the mass of the earth, Δm is the mass of "shell" above the point T, *G* is gravitational constant, *r* is the radius of the earth and *d* is the distance from the surface of the earth to the point T. Instead, on the basis of equations (1) and (3), we obtain: $g_T = \frac{mG}{(r-d)^2}$ (10). This means, for example, that according to our model gravitational acceleration g_T on the point T under the surface of earth will be bigger than the gravitational acceleration *g* on the surface of earth for the quantity $\Delta g = g_T - g$, namely $\Delta g = \frac{mG}{(r-d)^2} - \frac{mG}{r^2}$ (11). In particular, if we take *d*=4200*m*, on the basis of this formula we obtain $\Delta g = 0{,}012914 ms^{-2}$. Instead, according to the Newton formula the gravitational acceleration inside the earth will increase less because of the quantity $(m - \Delta m)$.

3. A-temporal gravitodynamics: wave nature of gravity-space and the role of the density of cosmic space

Several authors have considered the possibility that space is endowed with gravito/magnetic properties. In particular, in some recent articles [8, 9], Turanyanin proposed the idea of a gravity-space phenomenon characterized by a non linear wave dynamics in which the wave function describing the state of space is expressed in terms of two fields, the gravitostatic/electric $\vec{E}_g = \frac{G}{c^2}\frac{M}{r^2}\hat{r}$ (12) (having physical dimensions of a wave vector, L^{-1}) and the gravitokinetic/magnetic $\vec{B}_g = \frac{G}{c^2}\frac{\vec{J}}{r^3}$ (13) (having physical dimensions of a frequency) where $\vec{J} = \vec{L} + \vec{S}$, $\vec{L} = \vec{r} \times M\vec{v}$, *M* is the source mass, $\vec{S}$ is the spin angular momentum of the source.

Drawing a starting point from these recent results of Turanyanin, in this chapter we want to suggest a new view of a quantum gravity-space, endowed with a wave structure and in which time exists only as motion of matter. According to this interpretation, the most fundamental physical quantities describing space are the density of cosmic space (1) and a quantum vector $\vec{j}$ defined as $\vec{j} = \frac{G\vec{S}}{r^3}$ (14) and therefore having the dimensions of an angular momentum for unit of volume and multiplied with the gravitation universal constant. This quantum vector $\vec{j}$ can be therefore considered as a sort of "rotation-orientation" of each point of cosmic space. The quantum number *j* multiplied for r^3/G can assume integer or half-integer multiple values of the Planck reduced constant in order to assure consistency with the results of standard quantum mechanics. We will say thus that each point of the universal cosmic space is characterized by a determinate value of the density of cosmic space and is endowed with a particular rotation-orientation linked to a particular value of the quantum number *j* which can assume integer of half integer multiple values of $\frac{\eta G}{r^3}$.

In the theory here suggested, in analogy with the proposal of Turanyanin, space can be described in terms of two fields: the gravistostatic/electric field defined on the basis of the relation $\vec{E}_g = \frac{D(r)}{c^2}\hat{r}$ (15) (which is completely compatible with (12)) and the gravitokinetic/magnetic field defined on the basis of the relation $\vec{B}_g = \frac{D(r)\cdot v\cdot sen\vartheta}{c^2}\hat{b} + \frac{\vec{j}}{c^2}$ (16) where ϑ is the angle between $\vec{r}$ and the speed $\vec{v}$ of the particle associated with the density of cosmic field $D(r)$, $\hat{b}$ is an unitary vector identifying direction and versus of $\vec{L} = \vec{r}\times m\vec{v}$, *m* being the mass of the particle. The modulus of $\vec{B}_g$ is $B_g = \sqrt{\frac{(D(r))^2\cdot v^2\cdot sen^2\vartheta + j^2 + 2D(r)\cdot v\cdot sen\vartheta\cdot j\cdot\cos\eta}{c^4}}$ (17) where η is the angle between $\hat{b}$ and $\vec{j}$. It is important to observe that the gravitostatic/electric field (15) and the gravitokinetic/magnetic field (16) have the physical dimensions of a wave vector and a frequency respectively(compatibly with the view of Turanyanin). In analogy with Turanyanin's theory, it appears thus permissible to introduce the wave function of a quantum-gravity space

$$\psi_S = A\exp\left[2\pi i\left(\frac{D(r)}{c^2}\hat{r}\cdot\vec{r}_0 - \sqrt{\frac{(D(r))^2\cdot v^2\cdot sen^2\vartheta + j^2 + 2D(r)\cdot v\cdot sen\vartheta\cdot j\cdot\cos\eta}{c^4}}t + \varphi_0\right)\right] \quad (18)$$

where the amplitude *A* is a function of the point (*x*,*y*,*z*) of cosmic space. *A* will depend in general on the density of cosmic space and on the speed of the particle determined by this density of cosmic space. The wave function (13) of quantum-gravity space can be considered the starting-point of an a-temporal interpretation of the universe, in which time exists only as motion of matter. In fact, for *v*=0 and *j*=0 (conditions which mean no motion), one can easily see that this wave function assumes the form $\psi_S = A\exp\left[2\pi i\left(\frac{D(r)}{c^2}\hat{r}\cdot\vec{r}_0 + \varphi_0\right)\right]$ (19) namely turns out to be independent from time: this means just that when there is no motion there is no time.

In the particular case *j*=0 (which determines the presence of a particle with spin *S*=0), the wave function of quantum-gravity space (18) becomes $\psi_S = A\exp\left[2\pi i\left(\frac{D(r)}{c^2}\hat{r}\cdot\vec{r}_0 - \frac{D(r)\cdot v\cdot sen\vartheta}{c^2}t + \varphi_0\right)\right]$ (20). The phase speed of this wave is $v_\varphi = \lambda_S v_S = v\cdot sen\alpha$.

The wave function (20) can be considered as physically real, in the sense that is satisfies the scalar wave equation $\nabla^2\psi_S - \frac{1}{{v_\varphi}^2}\frac{\partial^2\psi_S}{\partial t^2} = 0$ (21) or possibly a more fundamental and general (non linear) Klein-Gordon equation $\nabla^2\psi_S - \frac{1}{c^2}\frac{\partial^2\psi_S}{\partial t^2} = {k_g}^2\psi_S$ (22). Because of the mentioned nonlinearity, there are obvious mathematical difficulties (for example, the quantization is a complex issue because there is no exact superposition principle) but on the other hand the scheme is put in promising dynamic perspective in the sense that linearity, superposition and the dependence of electromagnetic and gravitational interactions with $\frac{1}{r^2}$ can be seen only as approximate principles. Assuming $k_g = \frac{D(r)}{c^2}$ and speaking more “quantum-mechanically”, for time independent case equation (22) receives an interesting exponential but still non linear form $\Delta\psi_S = \frac{[D(r)]^2}{c^4}\psi_S$ (23).

The solutions of this equation (23) depend on the *r*-domain. Defining $r_g = \frac{D(r)\cdot r^2}{c^2}$ we have the following results:

1. For $r > r_g$, namely $D(r) < \frac{c^2}{r}$ (case of weak fields, such as planets), since $(r_g / r)^2 \approx 0$, equation (19) becomes the well-known Laplace equation $\Delta\psi_S = 0$ (24) whose domain is linear and where superposition is valid. This domain could be considered as classical vector gravity.
2. For $r < r_g$, namely $D(r) > \frac{c^2}{r}$, we have a totally non-classical domain (the so-called a “black hole” inner space) with non linear phenomena. This domain is characterized by the following wave equation $\Delta\psi_S = \left(\frac{D(r)}{c^2}\right)^2 \psi_S$ (25).
3. For $r = r_g$, namely $D(r) = \frac{c^2}{r}$, a strong field area is reached. In this case, from the de Broglie-like condition for circular orbits $2\pi r = n\lambda_S$, we have $r = \frac{2\pi r_g}{n}$ where $1 \le n \le 6$ if $r_g \le r$. In this domain the wave equation assumes the form $\Delta\psi_S = \left(\frac{D(r)\cdot r^2}{c^2}\right)^{-2} \psi_S$ (26) with well-known general exponential solutions.

Since in the approach here suggested space turns out to have a wave structure, in analogy with de Broglie’s postulate of the wave aspect of matter, a sort of resonance could be rightfully postulated $\nu = B_g$ (27) which means a direct natural connection between the quantum and gravitation features of a material object (and therefore between the quantum and gravitation features of a given region of space). Substituting $\nu = \frac{E}{h}$ where $E = m_0 c^2$ (according to de Broglie’s condition) and equation (15) into equation (27), in the case *j*=0 we obtain $\frac{m_0 c^2}{h} = \frac{D(r)\cdot v \cdot sen\vartheta}{c^2}$ namely $m_0 = \frac{D(r)\cdot h \cdot v \cdot sen\vartheta}{c^4}$ (28) where here m_0 is the mass of resonance. On the ground of equation (28), one can say that the appearance of a mass derives from the gravity-space dynamics: a density of cosmic space produces a frequency $\frac{D(r)\cdot v \cdot sen\vartheta}{c^2}$ in the surrounding space and then that region of space is able to vibrate with that frequency creating the appearance of mass. According to the view here presented, one can therefore say that each quantum of space is characterized by a frequency of vibration and each particle can be seen as the result of a resonance. For example, an electron, since has a mass of $9.109389754\times10^{-31}$, derives from a quantum of space which satisfies the following condition $9.109389754\times10^{-31}=\frac{D(r)\cdot 6{,}62607554\cdot10^{-34}\cdot v\cdot sen\alpha}{(2{,}99792458\cdot10^{8})^{4}}$ namely $D(r)\cdot v\cdot sen\alpha=111{,}0492713\cdot10^{35}m^{2}s^{-3}$.

4. A-temporal interpretation of general relativity

If time exists only as a stream of irreversible changes happening in space, also the results of general relativity can be reread in a-temporal sense. So, while in Einstein's original theory gravity was seen as a modification of the geometry of the space-temporal continuum at four dimensions, now the results of general relativity can be interpreted in the following way: gravity is transmitted by the density of the four-dimensional a-temporal space (where the fourth coordinate represents the numerical order of material changes) and its effect is to produce modifications in the geometry (i.e. in the curvature) of this a-temporal space [10]. All the laws of general relativity can be considered in a four-dimensional a-temporal physical space.

In particular, there prospects the following interpretation of the fundamental equation $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=kT_{\mu\nu}$ (29), i.e. of the tensorial equation of the gravitational field, equation which gives general relativity a complete logic structure and a definitive formulation. The term on the left of the equation, which Einstein defined "gravitational tensor", is composed by two terms, containing metric tensor $g_{\mu\nu}$, Ricci's tensor $R_{\mu\nu}$ and *R*, a number given by the composition of metric tensor and Ricci's tensor. The right-term of the equation is matter-energy tensor which (in Einstein's original view) represents the source of gravitational field, while the constant *k* is equal to $\frac{8\pi G}{c^{4}}$ where *G* is the gravitational constant and *c* is the speed of light in the vacuum. Equation (29) can be easily expressed in terms of the density of cosmic space (1). In fact, by multiplying and dividing equation (29) for the term r^{2} where *r* is the distance from the centre of the material object of mass *m* into consideration, we obtain: $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=\frac{8\pi}{c^{4}}D(r)\cdot\frac{r^{2}}{m}\cdot T_{\mu\nu}$ (30). It is also possible to introduce a new tensor $D_{\mu\nu}$ defined by the relation $D_{\mu\nu}=\frac{G}{r^{2}}\cdot T_{\mu\nu}$ (31). The tensor $D_{\mu\nu}$ can be interpreted as tensor of the "density of physical space". In this way, equation (29) can be written in the following way: $R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R=\frac{8\pi}{c^{4}}\cdot r^{2}\cdot D_{\mu\nu}$ (32) which represents the fundamental equation in our a-temporal interpretation of general relativity (where it is more appropriate to say that the source of the gravitational field is not exactly the distribution of matter-energy but indeed the density of physical space, described by the tensor of "density of physical space"). The content of this equation (32) can be synthesised in the following "imaginific" terms: "The four-dimensional a-temporal physical space acts on the regions characterized by different spatial density telling them how to move; the density of physical space retroacts on the whole four-dimensional a-temporal physical space telling it how to curve".

Also the relations describing typical effects predicted by general relativity (and then experimentally verified) such as the deviation of a ray of light due to the presence of the sun and the precession of the orbit of a planet due to its eccentricity, can be easily expressed in terms of the density of cosmic space existing in a given quantum of space. On the ground of equation (1), the deviation of a ray of light coming from a given star and caused by the presence of the sun can be expressed through the relation $\delta = \frac{4D_R \cdot R}{c^2}$ (33) where D_R is the density of cosmic space (due to the mass of the sun) in the points of cosmic space at distance *R* from the centre of the sun. Equation (33) shows clearly that the deviation of a ray of light coming from a star (and caused by the presence of the sun) depends on the density of cosmic space D_R at the distance *R* in which the ray of light passes from the centre of the sun. Equation (33) predicts that with the increasing of the distance *R* of the ray of light (coming from a star) from the centre of the sun, its deviation tends to decrease ($D_R \cdot R$ tends to decrease with the increasing of *R* because D_R diminishes with the square of *R*, on the ground of equation (1)).

Analogously, the precession of the perihelion of the orbit of a planet is given by the relation $\Delta\varphi = \frac{6\pi D_a \cdot a}{c^2\left(1-e^2\right)}$ (30), where D_a is the density of cosmic space (due to the mass of the sun) in the points of cosmic space situated at distance *a* from the centre of the sun, *e* is the eccentricity of the planet's orbit, $a = \frac{r_+ + r_-}{2}$ in which r_+ and r_- are the distances from the sun, respectively of the aphelion and of the perihelion (in other words, *a* represents the biggest semi-axis of the orbit of the planet). Equation (34) shows clearly that the precession of the perihelion of the orbit of a planet depends on the density of cosmic space existing in the points at distance *a* from the centre of the sun, namely at a distance from the centre of the sun equal to the measure of the semi-axis of the orbit. Analogously to equation (33), the term $D_a \cdot a$ diminishes with the increasing of a (namely with the increasing of the distance of the planet from the centre of the sun) because D_a diminishes with the square of *a* (on the basis of equation (1)). As a consequence, equation (34) predicts that the precession of the perihelion of the orbit of a planet decreases with the decreasing of the density of cosmic space (due to the sun) and therefore with the increasing of the distance of the planet from the sun. Mercury is characterized by a significant precession of its perihelion just because it is a planet situated at little distance from the sun and, therefore, in the points of its orbit, the density of cosmic space due to the sun, is big. The movement of Mercury is slower than the movement of the Earth just because Mercury, being at a less distance from the sun, is characterized by a bigger density of cosmic space than the Earth.

Besides, if in the standard interpretation of general relativity the speed of clocks increases with the increasing of the height in the gravitational field, now one can say that also this effect of de-synchronisation of clocks because of the height is a consequence of the different values of the density of cosmic space at different distances from the centre of the gravitational field. This effect regarding the speed of change (time) can be expressed with the following formula $T = T_0\left(1 - \frac{D_r l}{c^2}\right)$(35) where T_0 is the duration of an event measured by an observer on the surface of the earth, *T* is the duration of the same event measured by an observer situated under the surface of the earth at a distance *l* from the surface of the earth, D_r is the density of cosmic space existing in that point. Equation (35) shows clearly that the duration of an event measured by an observer situated at distance *r* from the centre of a planet depends on the density of cosmic space existing at such distance from the centre of the planet. As D_r decreases with the square of *r* with the increasing of *r*, equation (35) predicts that time *T* measured by an observer at distance *r* from the centre of a planet decreases with the decreasing of the density D_r of cosmic space (due to a planet) and therefore decreases with the increasing of the distance from the centre of the planet. This means that clocks run faster on the top of a high mountain than at the seaside under the mountain; in fact, the density of space is higher at seaside than on the top of a mountain because the distance from the centre of the Earth is greater, on the basis of equation (1). In analogous way, the density of cosmic space increases by going towards the sun and therefore the speed of time (speed of bodies and particles) becomes slower by going towards the sun.

Also the gravitational blue-shift of the frequencies in the motion of a photon from the surface of the earth toward the edge of a tower of height *l* can be seen as an effect of the density in a given point of cosmic space. Firstly, it can be expressed through the relation $\frac{\Delta\nu}{\nu'} = 1 + \frac{D_{R+l}\cdot l}{c^2}$ (36) where $\Delta\nu = \nu - \nu'$, ν is the frequency of the photon on the surface of the earth, ν' is the frequency of the photon at the top of the tower of height *l*, *R* is the radius of the earth, D_{R+l} is the density of cosmic space existing at a distance *R+l* from the centre of the earth, namely on the top of the tower. Equation (36) shows clearly that the frequency of a photon on the top of a tower depends on the density of cosmic space existing on the top of that tower. As D_{R+l} decreases with the square of *R+l* with the increasing of *l*, equation (36) predicts that the quantity $\frac{\Delta\nu}{\nu'}$ tends to decrease with the decreasing of the density of cosmic space (due to the earth) and therefore with the increasing of the height *l* of the tower.

Moreover, Schwarzschild metric (in polar spherical coordinates) assumes the following form in terms of the density of cosmic space: $ds^2 = c^2\left(1 - \frac{2D(r)\cdot r}{c^2}\right)dt^2 - \left(1 - \frac{2D(r)\cdot r}{c^2}\right)^{-1} dr^2 - r^2\left(d\vartheta^2 + sen^2\vartheta d\varphi^2\right)$ (37). Schwarzschild metric in the standard form $ds^2 = c^2\left(1 - \frac{2Gm}{c^2 r}\right)dt^2 - \left(1 - \frac{2Gm}{c^2 r}\right)^{-1} dr^2 - r^2\left(d\vartheta^2 + sen^2\vartheta d\varphi^2\right)$ can be seen as a consequence of the more fundamental equation (37), on the ground of the relation $m = \frac{D(r)\cdot r^2}{G}$. Since the density of cosmic space in the centre of a material object assumes the value (2) and thus is not infinite, on the ground of the interpretation here suggested, Schwarzschild metric (37) as a solution of Einstein tensorial equation (32), is valid also in the centre of a material object. Therefore, according to our interpretation, there is only one singularity of Schwarzschild metric and this is given by the condition $1 - \frac{2D(r)\cdot r}{c^2} = 0$ namely $r_s = \frac{c^2}{2D(r)}$ (38). Equation (38) defines the expression of the Schwarzschild radius in our interpretation of general relativity. As it is known, its physical significance is that it determines the horizon of events which can give place under certain circumstances to the formation of black holes. Therefore, we can now interpret the horizon of events as the distance scale defined by relation (38). In other words, we can say that it is equation (38) which defines the distance scale at which general relativity becomes crucial for the understanding of the behaviour of a region of physical space having density of cosmic space $D(r)$ in the generic point situated at distance r from the centre of a given material object.

5. Density of cosmic space, Mach's principle and a-temporality

In our interpretation of general relativity, the density of cosmic space can be considered the most fundamental quantity, the physical entity which determines the principal effects. In this section, we want now to show that the density of cosmic space plays an important role also in the gravitational induction of inertia, allowing a new interesting reading and interpretation of Mach's principle.

A broad consensus exists that Mach's principle suggests that local inertial properties arise as a consequence of the existence, distribution, and currents of mass-energy in the universe. And many authors would probably agree that any detailed realization of Mach's principle should be compatible with general relativity. Indeed, the major variants of Mach's principle existing today in the literature have the form of the stipulation of boundary and/or initial conditions on the acceptable cosmological models of general relativity. The boundary conditions selected differ in details but it is widely assumed that the origin of inertia is to be found in gravity.

The difference in the positions as regards Mach's principle depend on the view whether matter or space-time (or, eventually, an a-temporal space) is more primordial. That is, some argue that matter elsewhere determines the properties of space-time and in this way establishes local inertial frames of reference. Others instead think that inertial reference frames are figments of our imaginations, that inertial forces are the facts of our experience, which must be explained in terms of the distant matter of the cosmos. These views are the opposite sides of the same coin but, as Gribbin underlined, how one chooses to interpret particles, theories and formalism often has deep consequences in the understanding of physical reality [11].

Here we claim the thesis according to which the density of cosmic space is the fundamental physical quantity which transmits gravitational interaction, which determines the properties of a space of a-temporal nature and which determines the induction of inertia. This is, according to us, the essential physical content of Mach's principle.

In order to characterize better this point, let us consider, for example, the simple case of a test particle endowed with a translational motion under the action of an external force in an universe of otherwise constant matter [12]. The gravitational field that the matter in the universe exerts on our test particle is $\vec{F} = -\nabla\phi - \frac{1}{c}\frac{\partial \vec{A}}{\partial t}$ (39) where ϕ and $\vec{A}$ are the gravitational scalar potential and vector potential respectively. Here, the gravitational scalar potential can be expressed through the relation $\phi = \frac{1}{V}\int_V D(r)\cdot r \cdot dV$ (40) where V is the volume of physical space into consideration, $D(r)$ is the density of cosmic space associated with the matter into consideration in the generic point r (or better which determines the presence of the matter into consideration). Equation (40) integrates to $\phi = D(R)\cdot R$, $D(R)$ being the total density of cosmic space of the universe existing at a distance R equal to the radius of the universe from the point in which this density assumes the maximum value. Taking into account that this condition is true for arbitrary points in the universe, $\nabla\phi$ vanishes everywhere and thus no Newtonian interaction of the test particle with the density of cosmic space associated with the rest of the universe occurs. Inertial reaction forces arise from the three-vector potential which in terms of the density of cosmic space associated with rest of the universe assumes the form $\vec{A} = \frac{1}{Vc}\int_V D(r)\cdot r\cdot \vec{v}\cdot dV$ (41) where $\vec{v}$ is the speed of the test particle with respect to the uniformly distributed density of cosmic space. Since in the reference frame of the test particle the matter everywhere in the universe, corresponding to the density of cosmic space *D*(*r*), appears to have speed -$\vec{v}$, we may consider $\vec{v}$ as a constant and remove it from the integration. In this way we obtain $\vec{A} = \frac{\phi}{c}\vec{v}$ (42) namely $\vec{A} = \frac{\vec{v}}{Vc}\int_V D(r)\cdot r\cdot dV$ (42a). Substituting (42) and (42a) into (39) we have $\vec{F} = \frac{\phi}{c^2}\frac{\partial\vec{v}}{\partial t}$ (43) namely $\vec{F} = \frac{1}{Vc^2}\frac{\partial\vec{v}}{\partial t}\int_V D(r)\cdot r\cdot dV$ (43a) which tell us that the inertial reaction force an accelerated particle experiences depends on the density of cosmic space due to the rest of the universe in the point at a distance equal to the radius of the universe from the point where this density is maximum. In particular, on the basis of equation (43), the inertial reaction force an accelerated object undergoes is just the gravitational force exerted on it by the rest of the matter of the universe if $\frac{1}{Vc^2}\int_V D(r)\cdot r\cdot dV = 1$ (44).

As regards the gravitational induction of inertia in general relativity, the importance of the density of cosmic space can be shown directly by using Nortvedt's PPN formalism [13]. On the ground of the results of Nortvedt, a material object translationally accelerated by an external force undergoes a transient change in its mass because it drags inertial space along with it. The dragging of the inertial space with acceleration $\delta\vec{a}$ at each point $\vec{x}$ within the object depends on the density of cosmic space associated with the object in that point according to the relation $\delta\vec{a} = \frac{4\phi(x)}{c^2}\vec{a}$ namely $\delta\vec{a} = \phi = \frac{4}{Vc^2}\vec{a}\int_V D(r)\cdot r\cdot dV$ (45). From this relation the following important consequence derives: if the object accelerated by the external force is the universe itself, the condition implied by equation (45) for all of its parts to be dragged rigidly with it so that such hypothetical accelerations are undetectable for observers in the universe is the equality between $\delta\vec{a}$ and $\vec{a}$: this is the condition in order to preserve rigid dragging of observers and the principle of relativity. In this we obtain $\frac{4\phi(x)\cdot x}{c^2} = 1$ namely $\frac{4x}{Vc^2}\int_V D(r)\cdot r\cdot dV = 1$ (46) locally in the PPN representation of general relativity. This result is similar to the condition (44) obtained by Sciama's vector potential analysis. It is also important to observe that if inertial reaction are to be ascribed to gravity and thus to the density of cosmic space, the absolute value of ϕ is not arbitrary – it cannot be adjusted with an additive constant – because $\vec{A}$ depends on ϕ, not merely on the gradient of ϕ. Thus we see that Mach's principle is satisfied in general relativity if we are willing to admit that absolute gravitational potentials – and consequently the density of cosmic space - have real, observable effects.

It is also important to underline that Mach's principle has important consequences as regards the nature of time: as it has been proved by Woodward, if inertia is relative and gravitationally induced (or, even better, determined by the density of cosmic space, we can add now), Mach's principle kills our conventional conception of time, makes difficult to avoid killing time. The results of the "toy" model proposed by Woodward about the origin of inertial reaction can be found in [14] and can be so summarized. In the interpretation based on the retarded potential, the "causality" condition has to be invoked in order to suppress solutions of the evolution equations so that the energy flow corresponds to the observation. This has the effect to create the illusion that accelerations with respect to a scalar potential field produce inertial reaction forces. Since inertial reaction forces are local field-source interactions, they are instantaneous. But evidence for the existence of such a real scalar field is absent. In the immediate interpretation the instantaneity of inertial reaction forces is explained by choosing boundary conditions on a space-like hypersurface where initial data are stipulated that allow one to recover inertial frames of reference (not reactions forces per se) as the solution of elliptic, instantaneous constraint equations. Causality is implicitly inserted in this interpretation, because the boundary conditions must be chosen so that the constraint equations give back the result obtained in an integration down the past lightcone for the transverse component of $\vec{A}$. The interpretation based on the advanced potential requires neither the causality condition nor the artifice of using constraint equations to explain the behaviour of what is really an integration along the past lightcone. Instantaneous inertial reaction forces are recovered without suppressing solutions of field equations and energy flow is everywhere reasonable. Boundary conditions, however, must be assumed that lead to convergence of the integrals for the sources of the potentials along the future lightcone, and a simple event horizon is not necessarily sufficient to guarantee such convergence. Also the future already objectively exists in this interpretation. As regards time, all these interpretations being classical are completely equivalent: they are deterministic, so if we choose, we can assert the objective reality of the past and future, for they are inexorable.

From the point of view of quantum mechanics, on the basis of the results of Woodward, in the immediate interpretation of Mach's principle the weird consequences regarding timelessness will prove unavoidable. Besides, even if we admit the reality of advanced effects, we cannot avoid killing time. In synthesis, as Woodward argues, the price to pay in order to have a clarity of understanding in quantum mechanics is accepting radical timelessness.

6. Conclusions

Starting from the idea that the stage of the universe is an a-temporal physical space endowed with four dimensions (where the fourth coordinate, time, is a measure of the numerical order of material movements) and assuming that universal space has a granular structure, namely is composed by quanta of space having the size of Planck length, new perspectives are opened in the interpretation of gravity. All the most important properties concerning gravity can be derived from the density of cosmic space. The density of cosmic space is the universal property of each point of space which assumes the maximum value in the centre of a material object endowed with mass and diminishes with the square of the distance from this centre. The view of gravity suggested here allows us to interpret particles as physical entities which are not different at all from space: the property of mass can be in fact seen as an effect of the density of cosmic space. In other words, on the ground of the considerations made in this article, there opens the possibility to imagine the world not in dualistic terms (space and matter intended as different entities at all, as entities independent one from the other), but to think to fundamental entities, QS having the size of Planck length, characterized by a determinate value of the density of cosmic space. Moreover, according to the view here suggested, space-gravity turns out to have a wave nature and the appearance of mass can be seen as a phenomenon of resonance deriving from the vibration at peculiar frequencies of a density of cosmic space.

As far as gravitational interaction is concerned, one can say that it is transmitted by the density of cosmic space and is a-temporal and immediate. The result is that material objects move in the direction where the density of cosmic space is increasing. In other words, the masses attract each other as a consequence of a more fundamental attraction between areas characterized by different density of cosmic space: areas of bigger density of cosmic space attracts areas of less density.

Moreover, also the fundamental results of general relativity can be expressed in terms of the density of cosmic space. One can say that the movement of the density of cosmic space has the cosmic space to curve and that all the typical effects of general relativity are linked to the density of cosmic space characterizing the region of space into consideration. Finally, one can say that the density of cosmic space assumes an important role also in determining the inertia of material objects. This can be considered as the essential physical content of Mach's principle and represents the natural consequence of the fact that the density of cosmic space is the fundamental quantity which transmits gravitational interaction.

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