Perspectives about density of universal cosmic mass, density of space and the a-temporal gravitation

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

Abstract

Clocks are measuring systems for the numerical order, speed and frequency of material changes that run into space. Time does not run into space on its own, time exists only as numerical order, speed and frequency of material change. Stellar objects and particles move into space only and not into time. Gravitational interaction between material objects is the result of curvature of space that is determined by the granular structure of space. Density of the elementary grains of space depends on density of universal cosmic mass, higher is the density of universal cosmic mass lower is the density of grains of empty space. Density of empty space is the physical basis of its curvature. Material objects have a tendency to move into direction of lower density and higher curvature of space. Gravitational interaction mass-space-mass is immediate: the presence of a mass causes change of density of space, change of density of space causes gravitational motion. A mass acts on another mass indirectly via the change of density of empty space. Gravitational interaction between two masses is immediate: no time, namely no duration of motion of a particle or wave in space is needed to transmit gravitational interaction from one to another material object.

1. Introduction: time as a measuring system of frequency, speed and numerical order of material change

In Newtonian physics as well as in standard quantum mechanics, time is postulated as a special physical quantity that plays the role of the independent variable of physical evolution. Newton or Hamilton equations, as well as the Schrödinger equation, are introduced on the basis of the underlying assumption that there exists an idealized, absolute time t in which the dynamics is defined. However, it is an elementary observation that we never really measure t, that t does not ever appear in laboratory measurements: we rather measure the frequency, speed and numerical order of material change. What we realize in every experiment is to compare the motion of the physical system under consideration with the motion of a peculiar clock described by a peculiar thick. This means that the duration of material motions has not a primary physical existence, independent from matter.

Physical time is run of clocks in space. With clocks we measure frequency, speed and numerical order of material change that run into space. Time as a run of clocks in space implies that the duration of a material change has no existence on its own. Duration of material change is the result of measurement with clocks. Space itself is timeless: past, present and future do not exist in space. Universe itself is an a-temporal phenomenon[1]. The idea of "a-temporal universe" was already brought up in the second part of the last century by Gödel and Einstein who discussed the possibility that there is no time in the universe as science experiences it[2].

More and more modern researchers are challenged with the view that space-time is the fundamental arena of the universe. They point out that the mathematical model of space-time does not correspond to physical reality, and propose a "state space" or a "timeless space" as the fundamental arena.

For example, in *A New Geometric Framework for the Foundations of Quantum Theory and the Role Played by Gravity*, Palmer underlines that since quantum theory is inherently blind to the existence of such state-space geometries, attempts to formulate unified theories of physics within a conventional quantum-theoretic framework are misguided, and that a successful quantum theory of gravity should unify the causal non-Euclidean geometry of space-time with the a-temporal fractal geometry of state space[3]. Palmer introduces a new geometric law of physics about the nature of physical reality based on an Invariant Set Postulate. The Invariant Set Postulate conjectures that states of physical reality are defined by a fractal geometry *I* , embedded in state space and invariant under the action of some subordinate causal dynamics D_I . The postulate is motivated by two concepts that would not have been known to the founding fathers of quantum theory: the generic existence of invariant fractal subsets of state space for certain nonlinear dynamical systems, and the notion that the irreversible laws of thermodynamics are fundamental rather than phenomenological in describing the physics of extreme gravitational systems. The Invariant Set Postulate posits the existence of a fractionally-dimensioned subset *I* of the state space of the physical world (namely the universe as a whole). *I* is an invariant set for some presumed-causal (namely relativistic) deterministic dynamical system D_I ; points on *I*, called also "world states", remain on *I* under the action of D_I . World states of physical reality are those, and only those, lying precisely on *I*. It is important to underline that in Palmer's theory, the subset *I* of the state space is more primitive than the deterministic dynamical system D_I . Given *I*, $D_I(t)$ maps some point $p \in I$, a parameter distance *t* along a trajectory of *I*. Crucially, D_I is undefined at points $\notin I$: if states of physical reality necessarily lie on *I*, then points $p \notin I$ in state space are to be considered literally "unreal". For practically-relevant theories (such as quantum theory) the intricate structure of *I* is unknown and these points of unreality cannot be ignored. As regards the key question of how to represent quantum-theoretic states in a mathematically-consistent way for such points of unreality, the Invariant Set Postulate provides support to the search for an a-temporal description of physics: by treating the geometry of the invariant set as primitive introduces a fundamentally a-temporal perspective into the formulation of basic physics.

The view of physical time as a run of clocks in timeless space can be considered the most direct and natural development of Palmer's approach: it is an a-temporal description of motion in physics. Motion does not run in time. Time/clock is a measuring device for motion that runs in a timeless space.

Girelli, Liberati and Sindoni have recently developed a toy model in which they have showed how the Lorentzian signature and a dynamical space-time can emerge from a non-dynamical Euclidean space, with no diffeomorphisms invariance built in. In this sense this toy-model provides an example where time (from the geometric perspective) is not fundamental, but simply an emerging feature[4]. In more detail, this model suggests that at the basis of the arena of the universe there is some type of "condensation", so that the condensate is described by a manifold R^4 equipped with the Euclidean metric $\delta^{\mu\nu}$. Both the condensate and the fundamental theory are timeless. The condensate is characterized by a set of scalar fields $\Psi_i(x_\mu)$, i=1,2,3. Their emerging Lagrangian L is invariant under the Euclidean Poincarè group ISO(4) and has thus the general shape

L = F(X1;X2;X3) = f(X1) + f(X2) + f(X3); $X_i = \delta^{\mu\nu}\partial_\mu \Psi_i \partial_\nu \Psi_i$ (1).

The equations of motion for the fields $\Psi_i(x_\mu)$ are simply given by

$$\partial_\mu\left(\frac{\partial F}{\partial X_i}\partial^\mu\Psi_i\right)=0=\sum_j\left(\frac{\partial^2 F}{\partial X_i\partial X_j}\left(\partial^\mu X_j\right)+\frac{\partial F}{\partial X_i}\partial_\mu\partial^\mu\Psi_i\right) \quad (2)$$

The fields $\Psi_i(x_\mu)$ can be expressed as $\Psi_i=\psi_i+\varphi_i$ where φ_i are the perturbations around the solutions ψ_i of the above equation. The lagrangian for ψ_i is given by

$$F\left(\bar{X}_1,\bar{X}_2,\bar{X}_3\right)+\sum_j\frac{\partial F}{\partial X_j}\left(\bar{X}\right)\delta X_j+\frac{1}{2}\sum_{jk}\frac{\partial^2 F}{\partial X_j\partial X_k}\left(\bar{X}\right)\delta X_j\delta X_k+\frac{1}{6}\sum_{jkl}\frac{\partial^3 F}{\partial X_j\partial X_k\partial X_l}\left(\bar{X}\right)\delta X_j\delta X_k\delta X_l \quad (3)$$

where $\bar{X}_i=\delta^{\mu\nu}\partial_\mu\psi_i\partial_\nu\psi_i$ and $\delta X_i=2\delta_\mu\psi_i\partial^\mu\psi_i\partial_\mu\varphi_i\partial^\mu\varphi_i$.

Different choices of the solutions ψ_i lead to different metrics

$$g_k^{\mu\nu}=\frac{df}{dX_k}\left(\bar{X}_k\right)\delta^{\mu\nu}+\frac{1}{2}\frac{d^2 f}{\left(dX_k\right)^2}\left(X_k\right)\partial^\mu\psi_k\partial^\nu\psi_k \quad (4).$$

If one considers the specific class of equations of motion for which $\psi_i=\alpha^\mu x_\mu+\beta$, the SO(4) symmetry leads to $\bar{\psi}=\alpha x_0+\beta$ which shows that the choice of the coordinate is completely arbitrary. Hence the Lorentzian signature can be obtained for the condition $\frac{df}{dX}(\bar{X})+\frac{\alpha^2}{2}\frac{d^2 f}{\left(dX\right)^2}(\bar{X})<0$, $\frac{df}{dX}(\bar{X})>0$ and in this case the lagrangian becomes $L_{eff}=\sum_i\eta^{\mu\nu}\partial_\mu\varphi_i\partial_\nu\varphi_i$ where $\eta^{\mu\nu}$ is the Minkowski metric. Moreover, Girelli, Liberati and Sindoni have showed that by means of the change of variables

$$\begin{pmatrix}\varphi_1\\ \varphi_2\\ \varphi_3\end{pmatrix}=\Phi\begin{pmatrix}\phi_1\\ \phi_2\\ \phi_3\end{pmatrix} \quad (5)$$

with $\Phi^2=\sum_i\phi_i^{\,2}=l^2$ where l is related to Planck scale, a dynamical space-time emerges from L_{eff}, which is characterized by the Einstein-Fokker equations

$R=2\pi G_N T$ (6),

$C_{\alpha\beta\gamma\delta}=0$ (7)

where

$R=\frac{6}{l^2}T$ (8),

$T(\phi_i)=g^{\mu\nu}T_{\mu\nu}(\phi_i)=-\Phi^2\sum_i\eta^{\mu\nu}\partial_\mu\phi_i\partial_\nu\phi_i$ (9),

$g_{\mu\nu}=\Phi^2(x)\eta_{\mu\nu}$ (10)

(which shows that the gravitational degree of freedom is encoded in the scalar field Φ) and where G_N is proportional to l^{-2}.

The toy model developed by Girelli, Liberati and Sindoni shows in a clear way that time cannot be considered a fundamental reality, that at a fundamental level space is timeless: the picture of the universe provided by this model is a mathematical proof of the idea that duration of material change has no existence of its own.

On the other hand, also other authors have recently suggested that time as human experiences it has not an objective existence. For example, Woodward argues that Mach's principle leads to the conclusion that time, as we normally treat it in our common experience and physical theory; is not a part of fundamental reality[5]. As it has been showed by Woodward, if inertia is relative and gravitationally induced, Mach's principle kills our conventional conception of time, makes difficult to avoid killing time. Also in the context of quantum mechanics, on the basis of the results of Woodward, the immediate interpretation of Mach's principle determines the weird consequences regarding timelessness: the price to pay in order to have clarity of understanding in quantum mechanics is to accept radical timelessness.

Rovelli proposes the idea that time is not defined at the fundamental level (at the Planck scale), namely that, in the quantum gravity regime, time should be simply forgotten, that the concept of absolute time *t*, as used in Hamiltonian mechanics as well as in Schrödinger quantum mechanics, is not relevant in a fundamental description of quantum gravity [6,7,8].

Julian Barbour says in *The Nature of Time*: "I will not claim that time can be definitely banished from physics; the universe might be infinite, and black holes present some problems for the time picture. Nevertheless, I think it is entirely possible, indeed likely, that time as such plays no role in the universe" [9].

In virtue of the argumentations and researches that we have mentioned here it seems permissible to assume that universe is a timeless phenomenon: universe does not run in time, time is not part of the universe, clock/time is merely a measuring system for the numerical order of physical events. Duration of physical events has no existence on its own: duration is result measurement with clocks. Space-time is merely a mathematical model and is not the fundamental arena of the universe.

2. Density of universal cosmic mass, density of empty space and the curvature of space

Two of the greatest achievements of physics in the last century were Einstein's general theory of relativity and quantum theory. Each of these theories has been extremely well tested and has been very successful from the predictive point of view. However, these theories are mutually incompatible. Thus our basic understanding of nature is not only incomplete and fragmented – but inconsistent. One clearly needs a new consistent theory describing the so-called "quantum gravity domain" which provides a unitary picture of the universe, incorporates the principles of both quantum mechanics and general relativity, and reduces to them in appropriate limits.

In order to find a novel picture of the world, the starting-point perspective of the author of this article is that space-time is not the fundamental physical arena of the universe, that space-time cannot be considered a primary physical structure. Already Einstein in his book *Relativity: The Special and General Theory* suggested that it makes no sense to think about space-time as an independent physical entity. The basic medium into which material change occurs is the gravitational field, namely a "space-matter structure", in other words a gravitational space. Space-time can be thus seen only as a structural quality of a gravitational field: "Space-time does not claim existence on its own but only as a structural quality of the [gravitational] field" [10].

In General Theory of Relativity the gravitational interaction is the result of curvature of space. Stellar objects change geometry of space. Massive objects move in the direction of higher curvature of space. Bigger is the mass of a stellar object, more space is curved, bigger is the gravitational field. So a coherent description of the quantum gravity domain must involve the quantization of space and time, something we have no previous experience with.

With Loop Quantum Gravity the suggestive idea arises that space has a granular structure. The picture of space provided by loop quantum gravity is mathematically precise and physically compelling: 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 $l_p^{\,3}$. 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

$A = 16\pi l_p^{\,2}\sqrt{j(j+1)}$ (11)[11].

Loop quantum gravity suggests thus that space is not indefinitely divisible but is composed by elementary grains, “quanta of space” at the Planck scale[12]. In this paper the suggestive idea is introduced that there is a link between granular structure of space and its curvature. If space is made out of elementary grains it is possible that space has different density. We will show that the density of space allows us to open interesting perspectives towards an a-temporal description of the gravitational interaction.

On the basis of the elementary perception, we can say that our experience of space is linked to the observation of material objects and that in the universe there are regions in which there is matter and regions devoid of matter. As a consequence we can suggest the idea that there are two quantities in order to describe the gravitational space: the density of universal cosmic mass and the density of empty space (called also density of the vacuum). Both the density of universal cosmic mass and the density of empty space depend on the amount of mass in a given volume of space. Higher is the density of universal cosmic mass, lower is the density of empty space. This view is in agreement with the second law of thermodynamics according to which every system has a tendency to the homogeneous distribution of energy. Also in the universe there is a tendency that energy is distributed in a homogeneous way. We have two basic energies in the universe: energy of matter and energy of empty space (gravitational energy) that are distributed in a homogeneous way: where energy of matter is high, energy of empty space is low and opposite. Energy of matter depends on the density of universal cosmic mass, while energy of empty space depends on the density of empty space.

The density of universal cosmic mass increases with the increasing of the amount of matter present in a given region of space. In particular, the density of universal cosmic mass associated with a material object of mass *m* in the points situated at distance *r* from its centre can be defined through the relation

$$D_m(r) = \frac{Gm}{r^2} \quad (12)$$

where *G* is gravitational constant. The density of universal cosmic mass can be considered an indirect measure of the gravitational acceleration.

The density of empty space decreases with the increasing of the density of universal cosmic mass and thus with the increasing of the amount of matter characterizing the region into consideration. The density of empty space can be defined by starting from general relativity. In general relativity the curvature of space can be considered as a measure of the density of quantum space. More space is curved, higher is the density of universal cosmic mass and less is the density of empty space. Less space is curved, less is the density of universal cosmic mass and higher is the density of empty space. Gravitational motion of massive objects is the result of change of density of quantum space. Change of density of quantum space is a physical basis for change of its curvature[13].

Let us consider the fundamental equation of general relativity

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = k T_{\mu\nu} \quad (13),$$

namely 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 (13) can be easily expressed in terms of the density of universal cosmic mass (12). In fact, by multiplying and dividing equation (13) for the term r^2 where *r* is the distance from the centre of the material object of mass *m* into consideration, we obtain:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi}{c^4} D_m(r) \frac{r^2}{m} T_{\mu\nu} \quad (14).$$

Now, we introduce a new tensor $D_{\mu\nu}$ defined by the relation

$$D_{\mu\nu} = \frac{r^2}{G T_{\mu\nu}} \quad (15)$$

and thus linked to the density of universal cosmic mass through the relation

$$D_{\mu\nu} = \frac{m}{D_m(r) T_{\mu\nu}} \quad (16).$$

Moreover, it is interesting to underline that this tensor is linked with the one form $e^I(x) = e^I_\mu(x) dx^\mu$ (which represents the gravitational field and is obtained by the metric field $g_{\mu\nu}(x) = e^I_\mu(x) e^I_\nu(x) \eta_{ij}$, η_{ij} being the Minkowski metric) by means of the relation

$$D_{\mu\nu} = \frac{\delta e^I(x)}{\delta A_{matter}} \quad (17).$$

where A_{matter} is the action associated with matter. In particular, a general relativistic system consisting of gravity and classical matter (namely without quantum effects) which emerges from a density of universal cosmic mass (12) can be obtained by the action

$$A^{matter}_{no-quantum} = \frac{c^4}{16\pi G} \int d^4x \sqrt{-g} R + \int d^4x \sqrt{-g} \frac{\hbar}{D_m(r)} \left(\frac{\rho}{\hbar^2} \partial_\mu S \partial^\mu S - [D_m(r)]^2 \rho \right) \quad (18)$$

where *S* is the Hamilton function. Equation (17) tells us clearly that the tensor $D_{\mu\nu}$ diminishes with the increasing of matter. On the basis of equations (15), (16) and (17) this tensor $D_{\mu\nu}$ can be appropriately interpreted as tensor of the "density of empty space". With the introduction of the tensor of the density of empty space, equation (13) can be written in the following convenient way:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi}{c^4} r^2 \frac{1}{D_{\mu\nu}} \quad (19)$$

which represents the fundamental equation in our a-temporal interpretation of general relativity (where it is more appropriate to say that the gravitational field is linked to the density of space, described by the tensor of "density of empty space"). The content of this equation (19) can be synthesised in the following "imaginific" terms: "The four-dimensional a-temporal physical space acts on the regions characterized by different density of empty space telling them how to move; the density of empty space retroacts on the whole four-dimensional a-temporal physical space telling it how to curve". Equation (19) shows clearly that the density of empty space can be considered the origin of the curvature of space.

The curvature of space increases with the decreasing of the density of empty space: in the regions where the density of universal cosmic mass is higher, the density of empty space is lower and it is this lower value of the density of empty space that causes an increasing of the curvature of space.

Finally, it is important to underline that the fundamental equation (19) can also be written in the equivalent way

$$r^2 = \frac{c^4}{8\pi} D_{\mu\nu}\left(R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R \right) \quad (20).$$

Equation (20) puts in evidence that the distance on square from the centre of a material object is directly proportional to the density of empty space. This suggests the possibility to interpret equation (20) as the equation which defines the idea of a metric distance in physical space that is tightly linked to the density of empty space. Equation (20) can be used to define the physical quantity "length" in the gravitational space. In other words, on the basis of equation (20) it turns out to be permissible to assume that the length in the gravitational space is tightly linked to the density of empty space, that is the value of the density of empty space which determines the value of the length into the gravitational space.

3. Density of empty space and the granular structure of space

In the quantum regime the fundamental equation of general relativity (19) becomes

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi}{c^4} r^2 \frac{1}{D_{\mu\nu}} + S_{\mu\nu} \quad (21)$$

where $S_{\mu\nu}$ is the quantum correction tensor given by

$$S_{0\mu} = -\frac{Q_G + Q_m}{2\sqrt{-g}} g_{0\mu}, \quad S_{ij} = \frac{1}{N} \frac{\delta(Q_G + Q_m)}{\delta g^{ij}} \quad (22)$$

where $Q_m = \hbar^2 \frac{N\sqrt{q}}{2} \frac{1}{\lfloor \Psi \rfloor} \frac{\delta^2 |\Psi|}{\delta \phi^2}$ is the quantum potential for matter and $Q_G = \hbar^2 N q G_{ijkl} \frac{1}{\lfloor \Psi \rfloor} \frac{\delta^2 |\Psi|}{\delta q_{ij} q_{kl}}$ is the gravitational quantum potential (here ϕ is the matter field, q_{ij} is the induced spatial metric, *N* is the lapse function, namely the function of the parameter τ which parametrizes the curve of the motion, G_{ijkl} is the super space metric, Ψ is the wave function satisfying the Wheleer-DeWitt equation). Equation (21) can also be written in the equivalent way:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi}{c^4} r^2 \left[\frac{1}{D_{\mu\nu}} + \frac{1}{D_{\mu\nu}^{Quantum}} \right] \quad (23)$$

where $D_{\mu\nu}^{Quantum} = \frac{8\pi r^2}{c^4} \frac{1}{S_{\mu\nu}}$ can be defined as "quantum density of empty space", which represents the quantum correction to the density of empty space, namely the contribution to the density of empty space determined by the quantum regime. Equation (23) can also be expressed in the appropriate and convenient way

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi}{c^4} r^2 \frac{1}{D_{\mu\nu}^{TOT}} \quad (24)$$

where

$$D_{\mu\nu}^{TOT} = \frac{D_{\mu\nu} \cdot D_{\mu\nu}^{Quantum}}{D_{\mu\nu} + D_{\mu\nu}^{Quantum}} \quad (25)$$

is the total density of empty space (classical + quantum). In this way, equation (24) tells us clearly that the density of empty space can be considered the origin of the curvature of space also in the quantum regime. Equation (24) tells us that it is just the total density of empty space (present on the right side of this equation) the fundamental physical entity which determines the curvature of the quantum space.

In synthesis, we can say that in the quantum gravity domain the complete set of equations to be solved is the equation (24), the Wheeler-DeWitt equation and the appropriate equation of matter field given by matter lagrangian. It must be noted here that solving the above mentioned equations is mathematically equivalent to solving the WDW equation and then using its decomposition to Hamilton–Jacobi equation and continuity equation, and extracting the Bohmian trajectories[14,15,16,17,18].

Moreover, it is interesting to underline that the tensor of the total density of empty space is linked with the one form $e^I(x) = e_\mu^I(x) dx^\mu$ by means of the relation

$$D_{\mu\nu} = \frac{\delta e^I(x)}{\delta A_{matter}^{total}} \quad (26).$$

where A_{matter}^{total} is the total action associated with matter. In particular, a general relativistic system consisting of gravity and matter with quantum effects can be obtained by the action

$$A[\bar{g}_{\mu\nu}, \Omega, S, \rho, \lambda]_{matter}^{total} = \frac{1}{2k}\int d^4x\sqrt{-\bar{g}}\left(\bar{R}\Omega^2 - 6\bar{\nabla}_\mu\Omega\bar{\nabla}^\mu\Omega\right) + \int d^4x\sqrt{-\bar{g}}\left(\frac{\rho}{\hbar D_m(r)}\Omega^2\bar{\nabla}_\mu S\bar{\nabla}^\mu S - \hbar D_m(r)\rho\Omega^4\right) +$$

$$\int d^4x\sqrt{-\bar{g}}\lambda\left(\Omega^2 - \left(1 + \frac{\left(\nabla^2 - \frac{\partial^2}{\partial t^2}\right)\sqrt{\rho}}{[D_m(r)]^6\sqrt{\rho}}\right)\right)$$

(27)

where $\Omega^2 = \exp Q$, $Q = Q_m + Q_G$ is the total quantum potential, a bar over any quantity means that it corresponds to no-quantum regime and λ is a Lagrange multiplier introduced in order to identify the conformal factor with its Bohmian value[19].

Now, analogously to the treatment made in chapter 2, equation (24) leads to the fundamental equation for the elementary distance in the gravitational space

$$r^2 = \frac{c^4}{8\pi} D_{\mu\nu}^{TOT}\left(R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R\right) \quad (28)$$

which tells us clearly that the length into the gravitational space is tightly linked to the total density of empty space (classical + quantum), that it is the contributions to the density of empty space determined by the classical regime and by the quantum regime which define the value of the observable “distance” into the gravitational space. As a consequence, if we assume, in accord with the philosophy of loop quantum gravity, that physical space has a granular structure at the Planck scale, we can deduce that the number of quanta of the gravitational space increases with the increasing of the density of empty space because the density of empty space increases proportionally just to the value of the distance on square from the centre of a material object (far away from stellar objects) and the number of the elementary grains of space increases with the increasing of the distance from the centre of a material object. In other words, on the basis of equation (28) the suggestive idea arises that the elementary area of physical space tends to diminish with the increasing of the density of empty space, that with the increasing of the distance from the centre of a material object (far away from stellar objects) the elementary area of the elementary grains of the gravitational space diminish in such a way that the density of empty space increases proportionally to the value of the distance on square r^2 from the centre of this material object.

If we start from the idea that the elementary surfaces of the physical space are determined by the values of the total density of empty space which characterize them, new perspectives are therefore opened in the image of the universe. In particular, according to the view here suggested the gravitational space can be seen as a "pool of free energy" made out of quanta of space (QS), uncreated basic quanta of energy that have a size of Planck volume or a multiple of this quantity. A new idea which can be introduced here on the basis of equations (20) and (28) is that the size of QS is flexible: in areas where there is no stellar object (namely far away from stellar objects) the density of universal cosmic mass is low, the tensor of matter-energy contains low values and thus the tensor of the density of empty space include high values and the size of empty QS is of Planck volume. In areas where the density of universal cosmic mass is high, the tensor of matter-energy contains high values and thus the tensor of the density of empty space include low values (and this happens near stellar objects and inside them) and thus the size of empty QS is bigger than Planck volume.

One can assume that QS which build up space are not connected in a rigid way. The gravitational space is a dynamic energy system where fluctuation of empty quanta of space follows motion of stellar objects and elementary particles. The elementary area of a region of space diminishes with the increasing of the density of empty space. Vice versa, lower is the density of empty space, smaller is the number of empty quanta of space in the unitary volume of space. Where density of empty space is lower quanta of space are more "stretched" and have a stronger tendency to "shrink". This "shrinking" force is gravitational force that works between quanta of space that are four dimensional. Gravity force keeps space together and keeps together also three dimensional objects that exist into four-dimensional space. For example between earth and moon gravity force works between four-dimensional "low empty density space clouds" (LDSC) of earth and of moon. It does not work directly between material objects, it works into space into which material objects are existing.

earth – LDSC of earth – gravity force – LDSC of moon – moon

Smaller is the density of empty space LDSC, bigger is the curvature of space. In General Theory of Relativity curvature of space can be considered as a measure for the density of empty space. Light is bend by passing massive stellar objects because of different density of empty space through which moves. Physical space into which stellar objects exist can not be curved on its own. Physical base of curvature of space is the variable total density of empty space (classical + quantum)[13].

According to the view here introduced (which can also be called the a-temporal interpretation of the gravitational interaction), gravity force acts between quanta of space, it is a "short distance force". Gravity does not work directly between stellar objects, it works in space in which stellar objects are existing: it is tied to the density of universal cosmic mass and the density of empty space. In virtue of opportune values of the density of universal cosmic mass and of the density of empty space, for example, the region of space around the sun has tendency to shrink and this is the gravitational force that pulls planets towards the sun.

4. Conclusions: the density of empty space and the timeless gravitational space

The curvature of space which arises from the total density of empty space (classic + quantum) acts as a direct information medium that generates the motion of material objects in a gravitational field. As a consequence, the “gravity medium” between stellar objects can be considered as a timeless space. Just like the information between two quantum particles in “Einstein-Podolski-Rosen” experiment does not travel between these two particles but is transmitted by a background space which is timeless and functions as an immediate, direct information medium, in analogous way the gravitational interaction between two material objects is not linked to particles or waves which travel between them but is transmitted directly by the timeless space through its fundamental properties represented by the density of the universal cosmic mass and the density of empty space.

One can say that at a fundamental level the curvature of space can be considered as a direct medium that generates gravitational motion of material objects into direction of higher curvature of space. There is no direct attraction force between material objects. Material object causes curvature of space and curvature of space causes gravitational motion. Gravitational interaction $mass \leftrightarrow space \leftrightarrow mass$ is immediate: presence of mass increases curvature of space that causes gravitational motion. Mass acts on other mass indirectly via curvature of space: $mass \leftrightarrow curvature \leftrightarrow mass$. Curvature of space is defined by Einstein curvature tensor:

$$G\mu\nu = \frac{8\pi G}{c^4} \cdot T\mu\nu \quad (29).$$

On the basis of the interpretation of space as a direct information medium, for example, the elapsed clock run for gravitational interaction between the earth and the sun is zero, the gravitational interaction between earth and sun is immediate in the sense that the curvature of space caused by the presence of the sun (given by Eq. 29) acts instantaneously on the earth determining its motion in its own trajectory. The sun acts instantly on the earth via the curvature of space (determined by the sun) which functions as a direct, immediate information medium between the earth and the sun.

In original papers of 1916 Einstein do not mention gravitational waves. This idea arises few months later. Einstein introduces gravitational waves as space-time perturbations (Einstein, 1916). With the introduction of gravitational waves that propagate with light speed gravity is interpreted a non-immediate phenomenon as propagation of gravitational waves requires some “tick” of clocks.

Loinger considers that gravitational waves are only hypothetical and do not exist in the physical world: “The gravitational waves are non-physical sinuosities generated, in the last analysis, by undulating reference frames”[20,21]. In the 1960s, Joseph Weber began his experimental work to detect gravitational waves. He was essentially alone in this field of research. Later, theoretical papers of Wheeler, Bondi, Landau and Lifshitz, Isaacson, Thorne and others, as well as experimental work of Weber, Braginski, Amaldi and others opened a new area of research in this field[22]. However, gravitational waves have not yet been detected. “To search for gravitational waves in a laboratory, classical or quantum mechanical detectors can be used. Despite the experiments of Weber (1960 and 1969) and many others (Braginskij et al., 1972; Drever et al., 1973; Levine and Garwin, 1973; Tyson, 1973; Maischberger et al., 1991; Abramovici et al., 1992; and Abramovici et al., 1996) and theoretical calculations and estimations (Braginski and Rudenko, 1970; Harry et al., 1996; and Schutz, 1997), gravitational waves have never been observed directly in laboratory”[23]. Therefore, we can conclude that no experimental evidence exists until now against the interpretation of gravity as immediate physical phenomenon caused by the curvature of space which acts as a direct information medium which arises from the total density of empty space (classic + quantum).

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