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Gravity originates from variable energy density of quantum vacuum

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Abstract: The physical understanding of the real mechanism of gravity is one of the most important questions in Physics. As we have already shown in a previous paper, the rest and relativistic mass of an elementary particle or body can be considered as having their origin in the diminished energy density of a Quantum Vacuum, characterized by a granular structure quantized through a Planck metric. The presence of massive bodies, from the scale of elementary particles to that of stellar objects and black holes, then determines Quantum Vacuum energy density gradients. In this paper we have proposed a novel physical model in which gravity is generated by the pressure of Quantum Vacuum in the direction of its own higher to lower density due to the presence of material objects or particles. In this picture gravity is an immediate and not – propagating action – at – a – distance interaction, resulting from the Quantum Vacuum dynamics, in turn related to fundamental properties of space itself only, not requiring the existence of the hypothetical graviton. Furthermore, the possibility to consider this Quantum Vacuum as a Bose – Einstein like condensate allows us to recover the large – scale description of the Universe consistent with General Relativity, viewed as the long – wavelength geometro – hydrodynamic limit of the Quantum Vacuum dynamics. The proposed model is also able to give a very simple explanation of: the equivalence between inertial and gravitational mass, the origin and dynamical behavior of dark matter and dark energy, the physical meaning of singularity in black hole, as well as to overcome some of the main difficulties of the Higgs model. Finally this model of gravity can be used as a starting point for a novel interpretation of the recently published data of BICEP2 radio telescope about the presumed indirect observation of gravitational waves.

Keywords: Gravity, Quantum Vacuum, Energy Density, Graviton, Gravitational Waves, Bose – Einstein Condensate, Dark Energy, Dark Matter

1. Introduction

The real origin of gravity is one of the most important, complex and substantially yet unsolved questions in Physics. Newton itself, who firstly gave a mathematical law of gravity, was fully aware of the need for a physical understanding of the mechanism of gravity. The replacement of the Newtonian model of gravity with the Einstein's one given by General Relativity (RG) has only shifted the question without solving it. Within GR, gravity has two possible interpretations: a field one and a geometric one. According to the latter, that has become the prevalent one, gravity is due to the curvature of the space – time "tissue", represented as a "rubber sheet", due to the presence of a mass. Nevertheless, this is a purely mathematical description telling nothing about the physical mechanism starting the motion. In fact, even supposing the existence, in the neighbouring of a source mass, of a curved four – dimensional manifold it doesn't explain why a second particle at rest should move towards the source mass. We cannot say it goes down toward source mass, simply because there is no "down" without already assuming the existence of gravity itself. Consequently, in spite of its mathematical success this model doesn't give a physical causal origin of gravity. On the other hand, the approach based on GR field equations, although physically more robust, presents even more critical problems [1]. In fact these fields should represent a kind of entity able to "propagate" the action from the source to target mass at faster than light velocity [2,3], so contradicting one of the fundamental postulates of Special Theory of Relativity (STR) on which it is based and, in particular, as commonly

assumed, the causal principle as well.

Nevertheless, several recent researches have shown [3,4] that, despite its mathematical correctness and agreement with most experimental results, the STR, in its original formulation, yet could be a not completely correct physical description of reality. In fact it has been shown that different and perfectly valid alternatives to "standard" STR, based only on the universal principle of homogeneity of space and time, can be achieved without considering the postulate of the invariance of the speed of light in all the inertial frames [4]. In some of these alternatives, in particular, the propagation of superluminal signals SLS doesn't violate the causal principle as it occurs when using the Inertial Transformation of space and time [4,5].

This means it is possible to adopt a field based theoretical approach like that of GR, able to reproduce its experimental evidences, without incurring causal paradox and supported by a clear physical mechanism originating gravity. This is possible only through a new formulation of the concept of physical space and its properties.

The idea of 19th century physics that space is filled with "ether" did not get experimental prove in order to remain a valid concept of today physics in its original formulation. On the other hand, the conception of 20th century physics that universal space is "empty", deprived space of its physical value, is contradictory because in physics we consider matter and energy as real entities and it is obvious that they must exist in "something" having some concrete physical features.

The flawed idea that material objects could exist in some empty space has generated some unsolvable problems about the physical origin and the meaning of mass and gravity. On the other hand, 20th century theoretical physics brought the idea of a Quantum Vacuum as a fundamental medium subtending the observable forms of matter, energy and space.

According to the Standard Model (SM), the total vacuum energy density has at least the following three contributions: the fluctuations characterizing the zero-point field, the fluctuations characterizing the quantum chromo-dynamic level of sub-nuclear physics and the fluctuations linked with the Higgs field. Moreover, one can speculate that there are also contributions from possible existing sources outside the SM (for instance, grand unification theories, string theories, etc.). Nevertheless the SM is far from representing a complete and definitive picture of physical reality, being it affected by worrying defects and deficiencies. In particular it is simply not able to describe the fundamental force of gravity, the presence of so much matter in comparison to anti – matter.

Another fundamental fault of SM is its inability to explain the origin of about the 96 % of the matter in the Universe, probably composed of non – baryonic matter, and generally classified as the sum of Dark Matter (DM) and Dark Energy (DE) that today we know drive the overall evolution of the Universe at large scales.

Within the SM, as we'll see in the following, the Higgs mechanism, that should explain the origin of mass for the 4% of "visible" matter of the Universe, is characterized by many other theoretical difficulties and cannot be considered as exhaustive.

The missing inside of physics of 20th century is that an area of universal space which theoretically is void of all fields, elementary particles and massive objects still exists on its own and so must have some concrete physical origin. The so-called "empty space" is a type of energy that is "full" of itself, having here its own independent physical existence. We do not "resurrect" the idea of ether, at least in its original formulation, here, we just point out that the concept of "empty space" deprived of physical properties is a most flawed and a-priory accepted concept in the physics of 20th century.

In this paper we'll show, starting from a novel model of a Quantum Vacuum, that not only inertial mass but also gravitational mass can be assumed as arising from the variation of Quantum Vacuum energy density. This opens the door to a new idea of gravity as dynamically originated by the Quantum Vacuum energy density gradients $\Delta\rho_{QV}(\vec{r})$ due to the presence, in the 3D physical space, of massive bodies and particles.

The proposed model of gravity, as we'll see, doesn't require the existence of the hypothetical graviton, so far never observed, being considered as an immediate and not – propagating action – at – a – distance interaction, resulting from the Quantum Vacuum dynamics, in turn related to fundamental properties of space itself only.

This picture also allows us to give a simple explanation of the Equivalence Principle (EP) and of the origin and behavior of Dark Matter (DM) and Dark Energy (DE), so overcoming the main difficulties of the Higgs model in this sense. Finally, the description of the Quantum Vacuum physical states in terms of energy density is consistent with the description of the Quantum Vacuum as a Bose – Einstein like condensate, whose long – wavelength geometro – hydrodynamic limit also gives the large – scale description of the Universe consistent with the predictions of GR.

2. Inertial Mass, Gravitational Mass and Gravity Originate from the Diminished Energy Density of Quantum Vacuum

The existence of a fundamental medium, able to reproduce the dynamical features of a concrete universal space and, in reality, constituting the deepest essence of universal space itself, is furthermore an ontological necessity in order to obtain GR as the mathematical description, in the low energy - long wavelength limit, of the space elementary structure and to create the bridge between Quantum Mechanics (QM) and General Relativity (GR). This could finally lead to the proper theory of quantum gravity, in which the quantization will be made on

the field function $\Phi(x)$ describing Quantum Vacuum and not on collective macroscopic variables constructed from it, as substantially occurs in all the proposed and commonly accepted alternative theories of quantum gravity.

As far as the role of the different contributions to the vacuum energy density, Timashev already examined the possibility of considering the physical vacuum as a unified system governing the processes taking place in microphysics and macrophysics [6]. Starting from the above fundamental considerations, we have already proposed [7] a novel model of Quantum Vacuum consisting of a granular structure of the universal space, similar to that assumed, for example, in many version of loop quantum gravity, but conceptually very different and based on the conception of a physical 3D space composed by energetic packages having the size of Planck volume:

$$V_P = l_P^3 \tag{1}$$

where l_P is the Planck length, representing its most elementary structures, defined in terms of fundamental physical constants only. This Quantum Vacuum also identifies a preferred inertial frame, quantitatively defined by space and time Inertial Transformations (IT) [5], respect to which mass can be considered as a convenient definition of energy itself, in turn related to homogeneity, in space and time, of the 3D physical space, then being the mass ultimately a manifestation of the energy of Quantum Vacuum. More precisely [7], rest mass and relativistic energy of a free particle or body can be considered as arising from the diminishing of this Quantum Vacuum energy density. Furthermore, in this model [4], time exists only as a mathematical parameter quantifying the duration of changes occurring in physical states of a system, and the crucial role is played by 3D physical space characterized by Quantum Vacuum energy density originating inertial mass.

The presence of a given material object in a given area of Quantum Vacuum diminishes its energy density inside and around a material object or particle [7].

In a fixed volume of physical space, a given isolate system has a total energy we can express as

$$E_{QV} + E_{em} + E_M = D \tag{2}$$

where E_{QV} is the Quantum Vacuum energy, E_{em} is the electromagnetic energy in the form of radiation, E_M is the relativistic energy in the form of matter and D is a constant.

This can be rewritten in a more general form, independent on the volume, in terms of density, also assuming that energy tends to a uniform distribution

$$\rho_{QV} + \rho_{em} + \rho_M = d \tag{3}$$

where ρ_{QV} is the Quantum Vacuum energy density, ρ_{em} the electromagnetic energy density, ρ_M is the relativistic energy density in the volume V and d is a constant energy density.

According to the assumed Planck metric, the Quantum Vacuum energy density, in the absence of matter and radiating electromagnetic fields, can be written as

$$\rho_{QV} = m_P c^2 / l_P^3 \tag{4}$$

where m_P is the Planck mass and l_P the Planck length. The value of ρ_{QV} can be considered as the maximum possible value of Quantum Vacuum energy density, representing the volumetric energy density averaged on all the frequency possible modes within the visible size of the universe.

According to the above results, we can then consider that every particle is made out of electromagnetic energy of Quantum Vacuum and so it consists of diminishing energy density of an ideal Quantum Vacuum. For massless particles, the diminishing of energy density corresponding to the "creation" of a particle of energy $E = \hbar\omega$ is given by

$$\rho'_{QV,E} = \left(m_P c^2 - \hbar\omega\right) / l_P^3 \tag{5}$$

where $\rho'_{QV,E}$ is the Quantum Vacuum energy density after the "expulsion" of the massless particle. For a massive particle of rest mass m we have instead

$$\rho'_{QV,m} = \rho_{QV} - mc^2 / V \tag{6}$$

where V is the proper volume of the body and the energy density variation is considered to be concentrated, for our purpose in this paper, in the center of mass of body.

According to Eq. 5 and Eq. 6 particles are made out of Quantum Vacuum energy "stuff", substantially made of electromagnetic field modes.

From Eq. 6 it immediately follows that mass can be expressed as a result of the variation of energy density of an "electromagnetic" Quantum Vacuum

$$m = \left(\rho'_{QV} - \rho_{QV,m}\right) V / c^2 \tag{7}$$

or equivalently

$$m = \Delta E_{QV} / c^2 \tag{8}$$

having defined $\Delta E_{QV} = \rho'_{QV} - \rho_{QV}$, and that energy of which particles are made up comes from Quantum Vacuum.

According to the above model, the Quantum Vacuum energy density inside and around a mass distribution is modified by the presence of the masses themselves. In particular, in the simplest case of two massive bodies or particles, if we schematically represent the diminished energy density zone associated of a given mass (as the white region including the mass in Fig. 1) we easily see that the Quantum Vacuum area between the masses is characterized by a lower energy density, this condition is more evident if the masses are sufficiently close to each

other such as the two zones of lower density overlap.

This mechanism determines a portion of space, between the bodies or particles, characterized by a lower energy density and explains the dependence of gravity strength on the distance between the masses. From a dynamical point of view, the area of higher energy density of outer Quantum Vacuum is pushing towards the area of lower energy density due to the presence of massive bodies or elementary particles.

This "pressure" is the physical origin of gravity as represented in Fig. 1. This theoretical model also simply explains the equivalence between inertial and gravitational mass, both being originated by the same Quantum Vacuum energy density diminishing for a given massive body or particle (see Fig. 1).

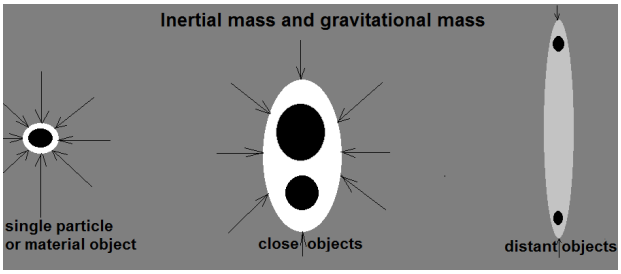

Figure 1. *Presence of a given material object diminishes energy density of Quantum Vacuum and this generates inertial mass and gravitational mass.*

Introducing the concept of energy density of Quantum Vacuum, the gravitational field existing at the point situated at distance *r* from the center of a given material object of mass, given by Eq. 8, assumes the form

$$\vec{g} = G\left(V/r^2\right)\left[\Delta\rho_{QV,m}\left(\vec{r}\right)/c^2\right]\hat{r} \tag{9}$$

Where $\hat{r}$ is the unitary vector indicating direction and orientation of $\vec{r}$. Equation 9 clearly shows that the gravitational field is a property of space that directly derives from the change of the energy density of Quantum Vacuum in the volume under consideration, and that gravity increases with the diminishing of the energy density of Quantum Vacuum.

The force of gravity between two masses m_1 and m_2 can be then written as

$$\vec{F}_{1,2} = G\left(V_1V_2/c^4\right)\Theta\left(\vec{r}_{1,2}\right)\hat{r}_{1,2} \tag{10}$$

where V_1 and V_2 are the physical volumes respectively associated to m_1 and m_2 while $\Theta\left(\vec{r}_{1,2}\right)$ is a function of the vector distance between the mass center of bodies describing the Quantum Vacuum energy density variation in the space between the masses. From Eq. 10 it is remarkable that the specific dependence of the function $\Theta\left(\vec{r}_{1,2}\right)$ on $\vec{r}_{1,2}$ is not a priori determined, meaning that there are in principle possible alternative forms of Newton's law characterized by different that r^{-2} (even time – dependent) behavior as supposed in some formulations of gravity like, for example, the gravitational analogue of Weber's law [8]

$$F = G\,m_1m_2/r_{1,2}^2 \times \\ \times\left\{1-\left(1/h^2\right)\left(dr/dr\right)^2+\left(2r/h^2\right)\left(d^2r/dt^2\right)\right\} \tag{11}$$

where $h=\sqrt{2}c$ or the generalized Newtonian force law proposed within the "Pressure - Induced Gravitation" (PIG) theories [9]:

$$a\left(r\right) = G\left(r\right)\left(1/r^2\right)m\left(r\right)e^{-\alpha(r)r} \tag{12}$$

where a is the acceleration and r the radial distance from m. Another very interesting feature emerging from our model is that the sign of function $\Theta\left(\vec{r}_{1,2}\right)$ can be positive or negative, depending on the relative importance of the different terms in Eq. 3 and, in particular, on the presence, in a given portion of space, of energy sources able to modify the Quantum Vacuum energy density.

This will allow us, as shown in section 5, to explain in a simple way the origin and the main properties of DE and DM.

The previous formulation of gravity can also explain the physical meaning of the singularities associated, in the current astrophysical approach, to black holes. In fact, inside the Schwarzschild radius (SR) r_S

$$r_s = 2Gm/c^2 \tag{13}$$

G being the gravitational constant and m the mass of a stellar object, we assume the energy density of Quantum Vacuum to be at its minimum constant value. Combining Eq. 6 and Eq. 13 we get the following expression for the energy density of Quantum Vacuum inside SR

$$\Delta\rho_{QV,s} = c^8/8\pi G^3m^2 \tag{14}$$

representing the minimum value of Quantum Vacuum energy density variation required for elementary particles stability. In our model, elementary particle cannot exist in an "empty space" deprived of physical properties; on the contrary, stability of elementary particles requires a minimum energy density of space, originating from Quantum Vacuum.

Inside SR areas elementary particles then revert to electromagnetic energy and further back to the energy of Quantum Vacuum.

This model resolves the paradox of singularities associated to black holes. From a physical point of view, black hole singularity just means that under the pressure, density and temperature inside the SR matter does not "vanish" from the physical universe but reverts to the energy of Quantum Vacuum. On the other side, in outer intergalactic space where energy of Quantum Vacuum is at maximum, the opposite process occurs, namely energy of Quantum Vacuum can turn into electromagnetic

radiation (so called "cosmic rays") that, in turn, can transform itself into elementary particles which constitutes matter [10]. This process of energy transformation "Quantum Vacuum – electromagnetic energy – matter – electromagnetic energy – Quantum Vacuum" determines a permanent dynamic equilibrium in the Universe.

This picture agrees with the so – called "equilibrium cosmology" (EC) which is based on two reliable assumptions and observations: the consideration of the blackbody spectrum of cosmic background radiation (CBR) and the cosmological data about the so-called "anomalous" redshift.

The first one is, in fact, substantially an equilibrium spectrum characterized by the equality of the CBR energy density with various local energy densities [9]. The consideration of the second aspect is much more complex and has very deep consequences on the Universe evolution at large scales. In fact a lot of empirical analyses would seem to show [9] that the universal redshift could be not a Doppler effect but simply the result of the interaction between light and matter or Quantum Vacuum energy, whose strength is proportional to the square root of the density, suggesting the space itself to be stationary. In this framework, black holes are "recycler" of higher entropy energy into "fresh" energy of Quantum Vacuum, which could have no entropy for definition. Observable increasing of entropy of the universe is then only a part of energy continuous transformation cycle.

In this view the Universe is a non-created system in which total energy cannot be created or destroyed according to the first law of thermodynamics (Fig. 2).

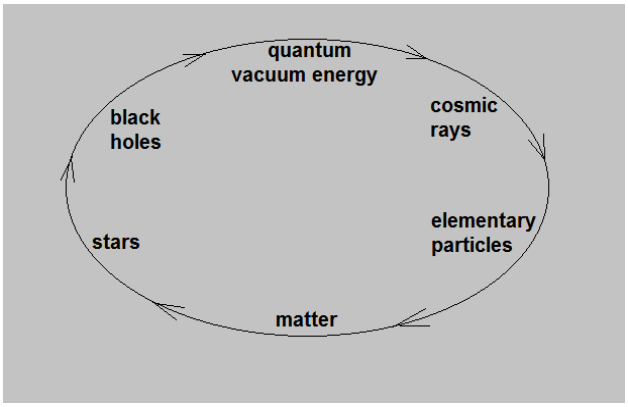

Figure 2. *Permanent energy circulation of the Universe.*

3. The Higgs Boson, the Higgs Field and the New Model of Quantum Vacuum

In the SM the mass of every elementary particles should result from the Higgs mechanism whose field is mediated by the Higgs boson, a not stable particle theoretically characterized by a energy of 125 GeV/c^2 and a lifetime of around 1.56×10^{-22} s [11]. The Higgs mechanism is based on "ad - hoc" hypothesis about vacuum potential energy field whose shape, instead of being just paraboloid like, is characterized by a little bump in the middle, forcing the field to "roll around" in a circular valley and, substantially, is part of a more general concept called symmetry breaking whose appearance cannot be justified, starting from fundamental physical principles only.

Apart from the yet unsolved doubts about the actual recent detection of Higgs boson at CERN, there are many theoretical difficulties that makes Higgs mechanism incomplete in order to fully explain the origin of mass. The first important question regards the origin of gravitational mass and its equivalence to inertial mass absolutely not considered in the SM that, as well known, is not be able to explain gravity; another question concerns the question of the so – called "neutrino oscillations" during which they would acquire a mass that Higgs mechanism cannot account to, a third interesting aspect, not explained by SM, is the "age-old" and yet unsolved question why the proton is exactly 1836 times heavier than the electron. Furthermore, from a purely epistemologically point of view, the Higgs model is not capable to answer to two critical questions: the first one is why photon does not interact with Higgs field, the second one is what gives mass to the Higgs boson itself [18]. The SM has serious difficulties in answering these questions.

On the other hand the model proposed in this paper is able to overcome a lot of these difficulties and in particular the equivalence of inertial and gravitational mass that is now simply explained since both are generated by the same Quantum Vacuum energy density diminishing as above discussed. In the proposed model, as we have shown [12], also massless particles interact with Quantum Vacuum, diminishing its energy density accordingly to their energy value $E=\hbar\omega$, so being valid from Planck scale up, a noticeable more general result than the Higgs mechanism.

4. Gravity "Propagation", the Graviton and its Epistemological Correlation with the Physical World

Graviton is a hypothetical particle that should transmit gravitational force. Within the SM, graviton is a massless particle characterized by zero electric charge, spin 2 and stable lifetime.

Let's consider two material objects A and B placed in universal space, and separated by a distance d. The *gravity element G* is supposed to transmit gravity between objects A and B. *Gravity element G in order to transmit gravity force between objects A and B needs to be in a simultaneous mutual physical contact with A and B*, according to the so called "Gravity theorem".

Gravity theorem requires a *direct epistemological correlation* between hypothetical gravity element G and gravity in physical world. In physical world the only

medium that is in a simultaneous mutual physical contact with material objects is physical space in which objects exist. In our model gravity is carried by variable energy density of Quantum Vacuum from which universal space arises. Our theoretical model of gravity is in direct epistemological correlation with actual gravity in physical world.

An hypothetical graviton moving from A to B does not satisfy "Gravity theorem". A theoretical model, based on the idea that a given particle could transmit gravity between objects A and B by moving in empty space on the distance *d* between them (called "spooky action at a distance"), has no *direct epistemological correlation* with physical world and could not to be taken in a serious consideration.

Gravity is a physical phenomenon that has no duration (time) and requires the *gravity element G* to be in a simultaneous mutual contact with the object A and object B.

In comparison with gravity, electromagnetism is a *propagating force* and is not immediate (being characterized by a duration). Gravity and electromagnetism are both transmitted from object A to object B or vice versa, via medium of Quantum Vacuum. The difference is that photon does not require simultaneous mutual physical contact with object A and object B as instead required by graviton as well as the Quantum Vacuum as a hypothetical *gravity element G*.

In the proposed model, gravity is *a non- propagating force* carried by the variable energy density of Quantum Vacuum and does not require the existence of mediator particles, because it originates from the dynamics between a given particle or massive body and the physical space in which it exists (since space itself is, in turn, a manifestation of Quantum Vacuum). In this picture, the Higgs field as well as the gravitational field is directly carried by field functions of the variable energy density of Quantum Vacuum. In this way our model is also in direct epistemological correlation with concrete physical phenomena of mass and gravity.

In our view, Higgs boson can be interpreted as a characteristic temporary change (duration of lifetime of around 1.56×10^{-22} s) of Quantum Vacuum energy density appearing after the collision of two protons and due to the "excitation" of Quantum Vacuum modes. Between hypothetical Higgs field and experimental results, indicating the existence of a particle called "Higgs boson", there is no direct epistemological correlation. Discovery of Higgs boson does not prove existence of Higgs field, nor that hypothetical Higgs field originates the mass of elementary particles. In general there is then no direct epistemological correlation between Higgs field, gravity field and a concrete physical mass/gravity phenomenon.

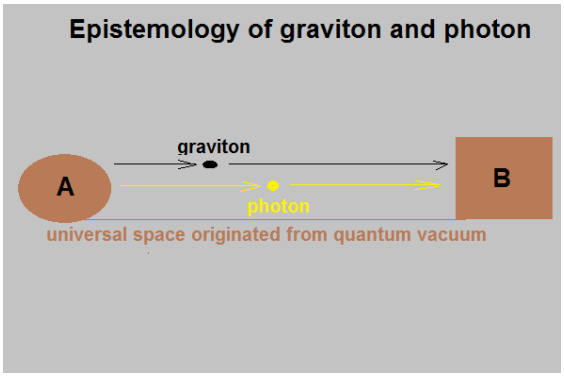

Figure 3. *Epistemology of graviton and photon.*

The second epistemological problem about the graviton is where it takes place in the material bodies or particles. We well know how photon is emitted and absorbed by matter but it is not the same about graviton (see Fig. 3). Emission and absorption of graviton from matter are still not clear from theoretical point of view [13, 14]. In our model hypothetical graviton has no necessary "epistemological stability" in order to be considered as hypothetical particle that carries gravity force. The same is valid for hypothetical gravitational waves (GW) that are supposed to be as ripples of universal space caused by groups of gravitons.

They are pure theoretical models which have still no confirmed physical existence [15, 16, 17], even after the recent supposed detection of GW from early Universe by the BICEP2 radio telescope at South Pole [18] that has not given any direct evidence of the existence of GW, and then of graviton.

In fact, the interpretation of these data is complex and not still unambiguous, potentially allowing, according to our model, also different interpretation of the phenomenon as will be shown in a forthcoming paper. Theoretical model of GW from early universe should be compatible with a previous model where GW are supposed to be emitted from binary stars [17]. In general, between the results which should indirectly confirm the GW existence and the theoretical model of GW there is, until now, no direct epistemological correlation.

The only known physical element, which satisfy "Gravity theorem" and is in simultaneous mutual contact with objects A and B, is then the universal space, provided with a suitable Quantum Vacuum structure of QED. In our model there is a direct epistemological correlation between mass/gravity phenomena and electromagnetic Quantum Vacuum of QED enriched by a Planck metrics. Further research are in progress in order to build a physical model having a direct epistemological correlation with the physical Universe within the framework of a *Bijective Epistemology in Physics* according to which to each element in the model correspond one an only one element in the Universe.

Between a physical model of the Universe and the Universe itself it must exist a direct epistemological

correlation, similar to that existing between two sets (in the Set Theory) related through a bijective function [4].

5. Energy Density of Quantum Vacuum, Dark Energy and Dark Matter

Today it is thought that around the 68% of the Universe is composed by the so – called DE, the 27% of the so – called DM and less then the 5% of ordinary matter. In the commonly accepted theory of the Universe, DE is a form of energy that opposes to gravity generating the expansion of the Universe. Its real origin is still a mystery: one explanation is that it could be a property of space itself that increase with the space expansion (Einstein's cosmological constant); another theory considers DE as a not better specified "fluid" or a "dynamical" energy filling the space; a third explanation calls into question the Einstein's theory of gravity, declaring it is not correct and that DE would not only affect the Universe expansion but also the behavior of normal matter as, in particular, the clusters of galaxies.

Nevertheless, despite the different explanations proposed by the mainstream physics theories, none of them can be considered, until now, satisfactory. DM, on the other hand, constitutes the bulk of the mass of the galaxies and it is fundamental for the formation of stars and galaxies, but is origin appears even more obscure; in this case we can certain say what DM is not: it cannot be made of baryonic matter, it cannot be constituted by antimatter (because it doesn't generate gamma ray bursts) and cannot be identified with the presence of galaxy - size black holes because of the analysis of the gravitational lens data.

The question of the origin and behavior of DM and DE can be considered, at least at a basic level, using the formalism given by Eq. 2, according to which the Quantum Vacuum energy density, in a given volume, can be written as

$$E_{QV} = D - E_{em} - E_M \tag{15}$$

then its variation, from an initial state 1 to a final state 2, in a given point, can be obtained through Eq. 15 and dividing by the volume

$$\Delta\rho_{QV} = -\left(\Delta\rho_M + \Delta\rho_{em}\right) \tag{16}$$

being $\Delta\rho_{QV} = \rho_{2,QV} - \rho_{1,QV}$ and $\Delta\rho_M = \rho_{2,M} - \rho_{1,M}$. From Eq. 16 we see that if $\Delta\rho_M + \Delta\rho_{em} > 0$ (as it occurs in correspondence to an increase of mass and electromagnetic radiation) then $\Delta\rho_{QV} < 0$ (the energy density diminishing above seen) but if $\Delta\rho_M + \Delta\rho_{em} < 0$, we have, conversely, $\Delta\rho_{QV} > 0$. In this case we experience an increase of local Quantum Vacuum energy density with respects its equilibrium value that, according to our model, can correspond to a repulsive force or, equivalently, to an anti – gravity that can be interpreted as the origin of DE. In the same way, the case $\Delta\rho_M + \Delta\rho_{em} > 0$ can be seen as the origin of DM whose effect is, from a gravitational point of view, similar to that occurring in the presence of usual matter only, but without the presence of the correspondent quantity of baryonic matter since the decrease of the term $\Delta\rho_M$ can be compensated by the increase of the term $\Delta\rho_{em}$ due to electromagnetic radiation.

The latter result agrees with the most recent hypothesis about the origin of dark matter, according to which, for example, it could consist of axions or sterile neutrinos [19]. But even more surprising, it can explain the results predicted by a very recent theory of DM, i.e. the "Cold Dark Matter" model or CDM, based on the data collected by Subaru Telescope in Hawaii [19]. According to CDM, in fact, the density of DM in the center of the most massive objects in the Universe, as for example the COMA cluster o galaxies, is lower than in the less massive objects, including our galaxy.

In our model this decrease of usual matter density could be compensated and exceeded by the density increase of an electromagnetic like energy density (the term ρ_{em}) representing in this case a sort of "dark radiation", a weakly interacting form of radiation, recently conjectured [20] that should mediate the interaction between dark particles, probably associated to the hypothetic sterile neutrino.

6. The Emergence of Space as Geometro – Hydrodynamic Limit of Quantum Vacuum Condensate

It has been shown that Quantum Vacuum can be described, under suitable conditions, by "metric elasticity" [21,22] in which the action of space

$$S(R) = -(1/16\pi G)\int dx\sqrt{-gR} \tag{17}$$

where R is the invariant Ricci tensor, can be viewed as a change in the action of quantum fluctuation of vacuum in a curved space. Basing on this assumption, and considering the consistent histories approach of quantum mechanics, according to which [21,22,23], the quantum evolution can be seen as the coherent superposition of virtual fine – grained histories, GR and space can be interpreted as the hydrodynamic limit of an underlying theory of "microscopic" structure of space.

A fine – grained history can be defined by the value of a field $\Phi(x)$ at the point x and its quantum amplitude as $\Psi[\Phi] = e^{iS[\Phi]}$, where S is the classical action corresponding to the considered history. The quantum interference between two virtual histories can be quantified by a "decoherence" functional

$$D_F[\Phi_A, \Phi_B] \approx \Psi[\Phi_A]\Psi[\Phi_B]^* \approx e^{i(S[\Phi_A]-S[\Phi_B])} \tag{18}$$

that gives the coarse – grained histories corresponding to

the observations in classical world. The quantum amplitude for a coarse - grained history is then defined by

$$\Psi[\omega] = \int D\Phi e^{iS}\omega[\Phi] \tag{19}$$

where ω can be considered as a "filter" function that selects which fine – grained histories are associated to the same superposition with their relative phases. The decoherence functional for a couple of coarse – grained histories is then

$$D_F[\omega_A, \omega_B] = \int D\Phi_A D\Phi_B e^{i(S[\Phi_A]-S[\Phi_B])}\omega[\Phi_A]\omega[\Phi_B]^* \tag{20}$$

in which the histories Φ_A and Φ_B assume the same value at a given time instant of the future, where decoherence indicates that the different histories contributing to the full quantum evolution can exist individually and are characterized by quantum amplitude and that the system undergoes an information and predictability degradation [23]: in this sense the system becomes stochastic and dissipative.

This formalism can be applied to hydrodynamics variables [23], through the following operator

$$T_{\mu\nu}(x_A, x_B) = \Gamma_{\mu\nu}\Phi(x_A)\Phi(x_B) \tag{21}$$

where $\Gamma_{\mu\nu}$ is a generic field operator defined at two points that satisfies the "conservation law"

$$T^{;\nu}_{\mu\nu} = 0 \tag{22}$$

meaning that the quantity that are most likely to be decohered, showing a classical behavior, are the conserved ones. It can be shown that, for an action $S[\Phi^l] = \Phi^l \Delta_{lm} \Phi^m$

$$\begin{aligned} &D_F\left[T^A_{\mu\nu}, T^B_{\mu\nu}\right] = \int DK^{\mu\nu}_n(x_A, x_B)\times \\ &\times\int \exp\left\{i\Phi^l\left[\Delta + K^{\mu\nu}_n(x_A, x_B)\Gamma^n_{\mu\nu}(x_A, x_B)\right]_{lm}\Phi^m\right\}\times \\ &\times\exp\left[iK^{\mu\nu}_n(x_A, x_B)T^n_{\mu\nu}(x_A, x_B)\right]D\Phi^l \approx \\ &\approx \exp\left\{i\Omega\left[T^A_{\mu\nu}(x_A, x_B), T^B_{\mu\nu}(x_A, x_B)\right]\right\} \end{aligned} \tag{23}$$

in which we have used the integral representation of delta and the CTP indices $l, m, n = 1, 2$, Ω being the closed –time path two – particle irreducible action [23].

The conservation of $T_{\mu\nu}$ implies that the decoherence functional has maxima in correspondence of hydrodynamic variables, density and pressure (ρ, p) that, in turn, *are the most readily decohered and have the highest probability to become classical*. The above procedure can be also applied to Einstein tensor $G_{\mu\nu}$ (having properties similar to those of $T_{\mu\nu}$) setting up an analogy between the conservation law for $T_{\mu\nu}$ and the Bianchi identity $G^{;\nu}_{\mu\nu} = 0$ which implies the decoherence and the emergence of the hydrodynamic variables of geometry. In this sense GR can be considered as geometro–hydrodynamics and the most readily decohered variables are those associated to the largest "inertia" representing the collective variables of geometry.

The classic world is then created by decoherence of the quantum microscopic structure of space, where conservation laws guarantee its persistence and stability, the last measured by the high – order correlation functions that characterize the effect of noise, fluctuations and dissipation from the environment. This offers to us a way to look at the interface between the classical and the quantum world since they are related to the tail of the quantum micro – structure of space.

7. Discussion

The understanding of the gravitation mechanism is one of the most important and yet unsolved problem in Physics. During the centuries, starting from the Newton's mathematical formulation of gravity law, two substantially antithetical positions have been in contrast: the Action - As –A – Distance (AAAD) approach and Local Action Theory (LAT).

The first one is characterized by several conceptual and experimental difficulties [24] as firstly pointed out by Newton itself that, in the *Principia* expressed its position against the mode of AAAD and the need for the search of a "material" transmission of gravitation within a framework called "Material Field Local Action" (MFLA). The currently accepted large – scale theory of gravitation, i.e. Einstein's General Relativity, can be considered as a Relativistic Local – Action theory (RLA), in which gravity acts through a metric field, generated by the geometrical properties of spacetime which itself depends on the distribution of matter.

Nevertheless, several well – founded criticism have been advanced, from the middle of the last century on, to RLA approach [9]. They are substantially related to redshift data [25], cosmological tests [26] and to the physical meaning of space and time itself [9]. With reference to the latter point, we have shown [4] that the commonly accepted interpretation of time as the fourth physical component of the Minkowski spacetime is not generally adequate, time being only a mathematical quantity giving the duration of a physical phenomenon. According to the MFLA approach, gravity is "transmitted" by a "material" stationary and all space – filling medium whose composition and propagation mechanism vary among the different formulations [9] and that it is supposed to be composed, in the modern conception, by gravitational and electromagnetic quanta (the hypothetical gravitons and the photons) forming the Quantum Vacuum.

However, in both RLA and MFLA, the key concept is respectively the field or the quantum field considered as the structure of the propagation medium in terms of space

dependence of density, velocity and energy of the interaction "transmitters". As we have seen, the most ambitious current quantum field description of reality, i.e. the SM, is not able to give satisfactory results in describing all the fundamental known forces in terms of elementary particles and quantum fields, first of all because it "simply" ignores gravity and because of epistemological difficulties affecting the Higgs mechanism as above briefly discussed.

In this paper we have proposed the suggestive idea according to which gravity originates from the diminished energy density of Quantum Vacuum, viewed as a condensate, caused by the presence a given material object or particle. From an ontological and dynamical point of view, gravity can be then explained as the action of a Quantum Vacuum "pressure" due to the energy density gradients created by massive bodies or particles in the 3D physical space.

In this model gravity is an immediate and not – propagating interaction due to Quantum Vacuum "pushing" acting from higher to lower energy density. From this point of view gravity, in our model, is not an AAAD interaction but a distance – depending force because of the dependence on the dimensions of the Quantum Vacuum volume in which energy density varies.

The proposed model is valid from the scale of the photon to that of the galaxies, so realizing the so much wanted unification of gravitational effects in systems on different scales.

But one of the most important feature of the proposed model is, without doubt, the ability to simply explain the equivalence between inertial and gravitational mass, both having origin, for a given body or particle, in the same decreasing of Quantum Vacuum energy density. In this sense it is able to explain the mass and the gravitational action of every particle, including the Higgs boson too.

Every mass in the Universe is then in a dynamical energetic relationship with Quantum Vacuum, modifying the vacuum energy density due to its rest mass plus kinetic energy. This modified energy density of Quantum Vacuum is the origin of "relative" velocity of material change including rate of clocks and is valid for all the observers [7,27,28].

Also relativistic effects of general relativity as gravitational redshift, bending of light rays, advance of the perihelion of Mercury, can be described within the proposed Quantum Vacuum model [27,28]. Also, in our view, curvature of space is only a mathematical description of universal space energy density diminishing caused by presence of massive bodies.

Finally, the proposed model is compatible with the dynamic space mathematically described by GR in in the low energy – long wavelength limit of the behavior of Quantum Vacuum.

8. Conclusions

The idea about dynamic energy density of universal space that depends on the presence of stellar objects is not new. Already Newton was thinking in a similar way: "Doth not this aethereal medium in passing out of water, glass, crystal, and other compact and dense bodies in empty spaces, grow denser and denser by degrees, and by that means refract the rays of light not in a point, but by bending them gradually in curve lines? ...Is not this medium much rarer within the dense bodies of the Sun, stars, planets and comets, than in the empty celestial space between them? And in passing from them to great distances, doth it not grow denser and denser perpetually, and thereby cause the gravity of those great bodies towards one another, and of their parts towards the bodies; every body endeavoring to go from the denser parts of the medium towards the rarer?" [29].

In our model mass and gravity are presented as a result of a dynamics between a given particle or massive body and the Quantum Vacuum in which particle or massive body are present.

The interpretation of the classical world described by GR as hydrodynamics limits of a microscopic theory of space permits the interpretation of space itself as the hydrodynamic state of a condensate quantum gas, like a Bose–Einstein Condensate (BEC), in which bosons experience a common collective coherent quantum behavior described by a macroscopic wave – function. In the low energy – long wavelength limit space could be viewed as a condensate, from some microscopic and more fundamental substructure, the Quantum Vacuum, in which the metric and its perturbation would correspond to collective variables and collective excitations or, alternatively, as a particular quantum state as a function of its elementary microscopic constituents, (like, for example, in string theory) similar to the ground state of a BEC. Due to the special features of the quantum wave function associated to a Bose – Einstein like condensate, the proposed framework could also able to explain the origin of mass, through a dynamical model under development, as a coherent phase transition of quantum states of this vacuum towards a more stable ground state than the perturbative QED or QCD [23].

An interesting perspective would be to extend the approach of the Quantum Vacuum energy density introduced in this paper also to the treatment of strong interaction, weak interaction as well as to the contributions linked to grand unification field theories outside the Standard Model. In this regard, the geometro–hydrodynamic model of the evolution of Quantum Vacuum could give, if adequately developed and improved, very important results since is well known [30] that the behavior of quark – gluon plasma is very similar, in many aspect, to the macroscopic behavior of an electron plasma; for this reason we can compare the magneto – hydrodynamics derived from Maxwell's theory to the magneto – cromo - hydrodynamics from QCD. The effective theories, describing the collective and coherent dynamics of their constituents, are respectively represented by atomic physic for QED and nuclear physics for QCD:

they can be viewed as low energy state collective stated of the same fundamental laws.

NASA research confirms that universal space is flat with only a 0.4% margin of error: “Recent measurements (c. 2001) by a number of ground-based and balloon-based experiments, including MAT/TOCO, Boomerang, Maxima, and DASI, have shown that the brightest spots are about 1 degree across. Thus the universe was known to be flat to within about 15% accuracy prior to the WMAP results. WMAP has confirmed this result with very high accuracy and precision. We now know (as of 2013) that the universe is flat with only a 0.4% margin of error. All we can truly conclude is that the Universe is much larger than the volume we can directly observe”[31].

The above results then strongly indicate that curvature of space in GR is only a mathematical description of energy density of universal space that originates in energy density of Quantum Vacuum. The development of a mathematical model that will connect energy density of Quantum Vacuum, curvature of space in GR and Higgs field is currently in progress.

In this connection, the geometro – hydrodynamic model of space as condensate could give an important contribution in the understanding of Quantum Vacuum since, if the Universe as a whole should be a quantum object (whose large scale behavior is controlled by a classic – like equation such the Gross – Pitaevsky equation in BEC theory [32]), the existence of vacuum energy density characterizing it as a quantum system could be immediately explained, unlike what happens in the generally accepted point of view in which it remains substantially mysterious.

Obviously, further researches and developments are necessary and in progress in this direction, first of all as regards the formulation of a complete dynamical model of Quantum Vacuum energy density also able to interpret, within the proposed model, the recent experimental data obtained by BICEP2 radio telescope at South Pole and those related to the diminishing of the orbital velocity of binary stars, as will be shown in a forthcoming work.

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