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Review Article

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The Nature of Vacuum Energy

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Abstract

The aim here is to show that the consideration of a quantum fluid, therefore granular, to describe space empty of matter and particles, is likely to resolve the question of its energy density in agreement with the data of standard cosmology. The Casimir effect should then make it possible to access its value which can be compared to the local gravitational energy. This also explains why quantum field theory is ineffective in accounting for this quantity.

We also show that we can, through this basic hypothesis, give a concrete meaning to "dark energy" and "dark matter".

1. Introduction

Here we address one of the main questions for which physics today remains without a satisfactory answer [1]. Quantum physics, through Quantum Field theory, admits that empty space is made up of an energy corresponding to the minimal state of the different fields that constitute it. It thus links it to the amplitude of quantum fluctuations directed by the uncertainty principle, but using the usual calculation method (summation of frequencies, renormalization), it leads to an absurd result (almost infinite) for the value of its density.

Relativity allows an experimental approach using Hubble's law, Einstein's equations integrate it using the "cosmological constant" in the limit state of expansion. It is found a density in the order of **10^-9 Joules /m^3**, but the nature of this energy remains totally mysterious.

The consideration of a granular and dynamic empty space, constituting a quantum fluid, was addressed in another publication we show here that it can make it possible to find, in order of magnitude, the previous value by giving it a concrete interpretation [2].

2. Vacuum Energy

According to our hypotheses the Vacuum, strictly speaking, presents two distinct phases representing dark matter and dark energy. The fundamental constituents, which we call QF, are equivalent to vibrators, or simple waves, they are unbreakable and their properties (energy, dimensions, etc.) are constants of infinitesimal values. For this reason, the vacuum energy density is a scalar function grouping the QF of the two phases in one location.

The first phase (dark matter), which I called "Brownian phase" or "gravitational phase" show high entropy and QF inside are in a state of diffuse movement with a static whole. The massive particles are in equilibrium with this medium, they create deficits there (by absorption of QF necessary for their stability), the deficit propagate in a straight line step by step under the effect of the gravitational field, it is the **graviton** which constitute "free wave" moving at the speed of light c and with negative energy. The energy density of this phase is that of the gravitational energy of the source mass, this by simple application of Stoke's law relating to a conservative flow of particles (gravitons). The formula giving this energy density is known :

(E) = M^2 G / 8 pi r^4 (1), where M is the mass of the source, G the gravitational constant, and r the distance from the center of mass.

Despite the state of disordered movement of the QF, this phase is static due to the internal balance between QF and gravitons (see below).

The second phase of the Vacuum is a dynamic phase, all the QF are engaged there in the form of positive gravitons (or anti-gravitons), they are therefore "free" waves moving (consequently) at speed c.

The energy density is thus the concentration of these anti-gravitons whose individual energy is a "constant" which is worth **e = h/T** where **T** is the age of the universe and **h** is Planck's constant.

This value was introduced by the interpretation of Newton's law in our corpuscular theory of gravitation (ref.2), we can also notice that it corresponds to the quantum limit of the application of the Elementary Action module **h (E.t = h).**

Empty space, empty from gravitational field, is then an anti-

graviton gas whose density is a space constant ; this gas is subjected to self expansion due to the fact that the temperature of space is not strictly zero; we find here the explanation of the accelerated expansion of the universe to the extent that this phase is the majority of vacuum energy (dark energy), we expect that its density is the lower limit of gravitational one (where there is no more QF).

There would be a lot to say about the application of these concepts to Cosmology, for example by detailing all the manifestations of dark matter (phase 1), we limit ourselves here to the description and calculation of the vacuum energy as well than to its experimental manifestations.

3. Calculation of Dark Energy Density

The gravitational phase involves the application of formula (1) by adding the contributions of all the sources that are the surrounding mass bodies; for example, the gravitational energy density of the Sun at the distance of the Earth's orbit is about **10^4 J/m^3** and it is close to **10^-3 J/m^3** at level of the planet Pluto. (Relation 1).

The second phase of the Vacuum, which is expanding and which can be called the "anti-gravitational phase", has a density which can be estimated, in higher value, by equalizing the gravitational energy density (1) to the energy density of the gravitons inside, produced by a mass M whose value is:

(Eg) = M c e / (4pi r^2 h) (see reference 2)

We then have the equation: M c e / (4 pi r^2 h) = M^2 G / (8 pi r^4) (2) whose solution is:

(Eg) = (E) = c^2 / (2pi GT^2) (3)

This expression shows that energy is a constant in space.

Taking T = 13.8 10^9 years for the age of universe, a calculation carried out with a precision of 1% gives:
(E) = 1,13 10^-9 J/m^3 (4)
This value can be compared to that of static equilibrium provided by the standard model of cosmology [3]., i.e.:
(E) = 3 (H^2 c^2) / (8 pi G) where H is the Hubble constant, which is an experimental quantity. If we take H = 2.2 10^-18 s-^1, we obtain
(E) = 0.78 10^-9 J/m^3
Our result is higher, that was expected, but it is of the same order of magnitude, so our value is compatible with standard cosmology in a quantum character way for our universe.

A question is why could quantum field theory not achieve this result ? (see reference 1), well, first of all, because it does not integrate gravitation field which is the basis of our interpretation.

We can deduce from equation (2) a very interesting relationship which is **r(g) = (M T G / 2 c)^0.5.**

It expresses the value of the gravitational maximal radius for a mass M. The numerical application of this formula to our galaxy makes it possible to find the mass-radius ratio that we know, that means that all the stars are under the gravitational influence of the galactic nucleus, which cannot surprise us and give a justification to the formula.

For the Sun, r(g) is close to 10^-2 AL, that is to say some ten times the radius of Pluto's orbit. (AL = light year)

4. The Casimir Effect; Experimental Manifestation of Vacuum Energy

The known, experiential manifestations of Vacuum energy are few; in addition to the exploitation of Hubble's law, there is the Lamb effect and the Casimir effect. We will only talk here about the latter, relating it directly to the energy of the vacuum as we propose it.

The Casimir effect consists of an external pressure observed on two conductive plates close together, this pressure **Pc** depends only on the distance d between the two plates according to the formula :

Pc = pi h c / (480 d^4) (4),

This formula was established by Casimir with a empirical method in 1948 [4]. The explanation, by the theory of Quantum Electrodynamics, is that the virtual photons composing the energy of the Vacuum exert an external radiation pressure on the plates, this increases sharply with their proximity because only the tuned photons then remain between the plates, however we cannot rule out an infinite value when the distance **d** tends towards zero.

We will show that we can advantageously replace these virtual photons by the QF of gravitational energy which are very real and permanent, of finite density and whose main properties have been established. We also know that the gravitational phase is very dominant in the terrestrial laboratory where the Casimir force is measured.

We spoke of “diffuse movement” of QF, it is also possible to draw a parallel with a gas whose molecules (with quasi-zero mass) would move in all directions at the speed of light, thus exerting pressure on any wall delimiting it .

We formulate the hypothesis that this pressure is precisely that of the Casimir effect Pc (4), which implies that we can reduce the distance d between the plates, up to a finite saturation value d(s) since so is the energy density. Practically, nothing then exists in the volume limited by the two plates and therefore the Casimir pressure is maximum there and d(s) measures the entire energy density of the local Vacuum.
We have to solve the equation which equalizes expressions (1), written in term of pressure, and (4), whose unknown is the saturation distance **d(s),** this equation is:

G M^2 / 24 pi r^4 = pi h c / 480 d^4 M and r are the mass and radius of the earth, respectively.

We find **d(s) = 4.8 10^-10 m** Such a value close to five times the diameter of a hydrogen atom is very difficult to measure, the “atomic force” microscope still allows, measurements down to

10 nanometers, which is very insufficient to assess saturation.
If we apply the same treatment to the limit of the gravitational range, whose energy density is a constant (3), the Casimir saturation distance is then: **d(s) = 3.2 10^-5 m (32 microns)**.
Without going so far, but freeing ourselves from the gravitational influence of the earth (at approximately 10^8 m from it), the value of d(s) would be of the order of one micron, which would allow the checking of saturation using the atomic force microscope, and thus measuring the vacuum energy density at this location.

5. Conclusion

Comments on the Nature of Vacuum Energy

We considered that the Casimir effect could be measured at any location in the cosmos in the gravitational phase and allow the local evaluation of the energy density of the Vacuum. We can also deduce that its constituents are electromagnetic in nature since it is necessary to make the plates conductive..., so what difference can there exist between a photon and the anti-graviton ? , in our opinion: none, and the anti-graviton would indeed be a photon of infinitesimal energy.

Phase 2, which is what we call "free energy", is then a gas of photons having very low energie which is the basic value e = h/T and whose density is the space constant slightly lower than (4), compatible with Standard Cosmology.

What can we say about the gravitational phase?, we saw that it was made up of two entities: a "sea" of "Brownian" QF and the gravitons which crisscross it, to which we must add that this phase is directed by a gradient of space which is the gravitational field of the mass-sources. Physics today (Relativity) considers this phase through the curvature of space-time, we linked this curvature to the mutual interaction between gravitons by momentum exchanges (reference 2), we also spoke about "unstructured matter".

All that recalls the main hypothesis which is that of the quantum fluid constituting Space. The gravitational phase could be then **a semicondensed electromagnetic phase** in equilibrium with the free particles of negative energy which are the gravitons, something looking like condensed phase in Helium superfluid.

All these considerations militate in favor of the search for a formal theory concerning quantum fluids constituted by infinitesimal particles (QF).The hypothesis of a quantum granular Vacuum Space makes it possible to eliminate infinities, but also to be able to assimilate "dark energy" to a gas of minimal , very low energy photons.

We also describe the gravitational field and all the manifestations of "dark matter" (…) by a particular phase of electromagnetism corresponding to an "unstructured matter", intermediate between the photon gas and the structured stationary photons or electrons, composing the ordinary matter.

This phase only exists in the presence of negative energy quantum's (the gravitons).
All that implies the acquisition of a formal theory of this Quantum Space.

We have also showed that the Casimir effect could, in this case, allow a measurement of the energy of the Vacuum by evaluating the saturation of the force of attraction of the plates (for tending the distance towards zero).

References

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4. Wikipedia page *"Casimir Effect"*.