Applied Physics Research; Vol. 8, No. 6; 2016
ISSN 1916-9639 E-ISSN 1916-9647
Published by Canadian Center of Science and Education

An Alternative Interpretation of Planks Law

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Received: September 26, 2016 Accepted: October 18, 2016 Online Published: November 28, 2016

doi:10.5539/apr.v8n6p75 URL: http://dx.doi.org/10.5539/apr.v8n6p75

Abstract

It is possible to interpret Planck's law as describing the energy content of the elements of a discrete space. From this conclusion, one can construct physical theory with recourse to not more then one single particle and one single law. This one article concerns the dark matter and dark energy problems, which seem to be both simply explainable if Planck oscillators (as elements of a discrete space) which possess a positive potential energy. Furthermore, it is shown that there exists a one to one correspondence between the distribution of this energy density and the geometry of space, a result that can eventually generate new insights on the geometry of space-time from a natural quantum perspective.

Keywords: Planck's law, discrete space, duality, space energy density, space mass density, cosmological constant, ground energy, Heisenbergs uncertainty principle

1. Introduction

Although there are today some different proposals on how to handle the observational effects of an accelerated expanding universe, it is mostly considered that the cause of this behaviour is some form of a non-vanishing energy content of the vacuum. It is also accepted that this energy content is constant in a cosmological timescale, thus possessing the characteristics of Einstein cosmological constant. On the other hand, dark matter is considered to be some kind of very low density substance that interacts only gravitationally and is peculiarly distributed around mass concentrations. However, saying that the nature of dark energy and dark matter are the two biggest mysteries of the moment is only partly true. They are in fact mysteries, but nonetheless not bigger than others who have the privilege of being older, not less puzzling and which I will defend are directly implicated on the solution of both these problems. Why and how can a photon, or any other particle, be in two different places at the same time? Some would say that the answer is trivial and results from the application of the Born interpretation of the Schr?dinger equation, which is (from a local-realist perspective) not really an answer to the question. Given the existence of such and many others fundamental questions, who is to say that not understanding the nature of dark matter and dark energy is not just the result of an incomplete body of knowledge? In fact, it is known from several experiments that Planck's law describes almost perfectly the spectrum of the CMB (Cosmic Microwave Background) radiation. The average energy density of these thermal photons is, for the temperature of T=2.726K:

$$\rho_e = \int_0^\infty \frac{8\pi\nu^3 h}{c^3\left(e^{\frac{h\nu}{k_b T}} - 1\right)} d\nu = \frac{8\pi^5 {k_b}^4 T^4}{15c^3h^3} = 4.2x10^{-14} Jm^{-3} \tag{1}$$

It just happens that this value is of similar magnitude one would expect for the energy density necessary to justify the value of a cosmological constant (Kowalski & Rubin, 2008; Betoule et al., 2014). On the other hand, if we take an effective photon mass corresponding to De Broglie conjecture (L.De Broglie, 1964):

$$E = mc^2 = h\nu \tag{2}$$

then we have that the effective average mass density of this same photon bath is:

$$\rho_m = \frac{1}{c^2}\rho_e = \frac{8\pi^5 {k_b}^4 T^4}{15c^5h^3} = 4.6x10^{-31} Kgm^{-3} \tag{3}$$

which is of the same order of magnitude expected for the dark matter density in our galaxy (Garbari, Read & Lake, 2011).

There are two main reasons for considering that these values are not more than a coincidence. On one side, we assume that photons are non-interacting and so they cannot create by themselves the negative pressure necessary to justify a cosmological constant. On the other hand, we assume that a photon is a particle that displaces itself in space at the speed of light and, as such, it has to be massless. But how sure are we that these assumptions hold? After all, one has to agree that De Broglie expression (2), (associating mass with a particle traveling at the speed of light) represents a serious paradox. I believe this paradox can be solved if one interprets Plancks law as describing the energy of the elements of a discrete space and light a pure wave (in fact a pulse). The elements of the discrete space, when excited by this pulse, simulate the directed momentum of a photon when the actual average velocity of their oscillations is null. In such a way, a photon (an element of a discrete space) has a real momentum and light, as a wave, does not have any restrictions to travel at the speed of light. For a wave to propagate throughout the discrete space and its elements to have mass, it is necessary that they be connected through a force. I will deduce that this repulsive force results in the accelerated expansion of the discrete space in good agreement with the expected value of a cosmological constant. On the other hand, the mass of the same elements of the discrete space is in perfect agreement with the expected density of dark matter in our galaxy. This way we have not only a simple explanation for both the dark matter and dark energy phenomena but as well an alternative explanation for the nature of light and of the photon. This picture seems to be fully compatible with Plancks law, and it is that demonstration that is at the core of this work. In the section 3. I will show that Plancks oscillators seem to have a well defined geometric spatial disposition, that this geometric disposition is responsible for Plancks constant and that Plancks oscillators must necessarily be connected through a repulsive force. Section 4. has the objective to show that light can be considered as a wave and a photon an element of a discrete space and to show that De Broglie conjecture (2) can be proved for this particular situation. A different expression for the ground potential is deduced as a prediction that can eventually be used to sustain or disprove this theory. Finally, in section 5. we will calculate the value of the cosmological constant and show that the parameter w of the equation of state does not precisely implies a cosmological constant but rather a special form of quintessence, here caused by a vector potential field rather then by a scalar one. If it would hold to scrutiny, one can easily extend the theory to show that the repulsive force mentioned above can represent the four fundamental forces within one single expression, a work I will develop in a future article.

2. On the Geometric Arrangement of Planck's Oscillators

For reasons which will be later easily understood, I will call the subjects to which Planck's law applies not photons but Planck's oscillators. The number of Planck's oscillators with frequency between υ and $\upsilon + \partial\upsilon$ in a volume of space V is (Planck, 1901; Bohm, 1951):

$$\partial N = \frac{8\pi V}{c^3}\upsilon^2\partial\upsilon \tag{4}$$

The number of oscillators in the volume is then:

$$N = \int_{\upsilon_1}^{\upsilon_2} \frac{8\pi V}{c^3}\upsilon^2\partial\upsilon = \frac{8\pi V\left({\upsilon_2}^3 - {\upsilon_1}^3\right)}{3c^3} \tag{5}$$

If we consider that the frequency v_2 is some multiple k of v_1, we have

$$N = \frac{8\pi V{\upsilon_1}^3\left(k^3 - 1\right)}{3c^3} \tag{6}$$

Rearranging and writing the result in terms of the wavelength λ=c/v1

$$N^* = \frac{N}{(k^3 - 1)} = \frac{8\pi}{3}\frac{V}{\lambda^3} \tag{7}$$

Note that N*=N/(k^3-1) must also be an integer number. This formula has similarities with the expression describing the number of elements in a lattice, generally:

$$N_l = nd\frac{V}{V_c} \tag{8}$$

where Vc is the volume occupied by each lattice cell, d the packing fraction characteristic of the lattice system and n the number of vertices of the unit cell. From the 14 lattice systems that can exist in a tridimensional space (known as the Bravais lattice systems) there is one lattice that makes (7) exactly equal to (8). This is the simple cubic lattice with 8 elements, a volume packing fraction of d=π/6 and lattice cell volume of i3, being i the distance between the lattice elements. The number of elements (8) in this lattice system is then:

$$N = 8\frac{\pi}{6}\frac{V}{i^3} \tag{9}$$

In a move that will become clear later on, we turn back to Planck's oscillators as photons. Considering that a photon can have two polarisation states, the actual number is twice that much, that is:

$$N = 2x8\frac{\pi}{6}\frac{V}{i^3} = \frac{8\pi}{3}\frac{V}{i^3} \tag{10}$$

and we recover (7) in the case that:

$$\lambda = i = \frac{2\pi c}{w} \tag{11}$$

where, by definition, w is the radial frequency exciting any one particular oscillator. Although this result can be considered far from being a sufficient condition, it implies that Planck's oscillators form a geometric arrangement like that of a simple cubic lattice, a radical departure of the usual interpretations of Plancks law and the nature of photons. That Planck's oscillators would organise themselves in a lattice would make no sense if we consider Planck's oscillators as photons and a photon as a particle that displaces itself in space at the speed of light. But it starts making sense if we consider light to be a wave propagating in a lattice of elements (similar to phonons), being the lattice elements Planck's oscillators.

It is now necessary to give a physical interpretation to the nature of these lattice elements or Plancks oscillators. We seem to have two different options: 1) The lattice elements are the constituent molecules of an aether (Diracs sea of electrons here included, although it is possible to show that the lattice elements cannot be and are not electrons); 2) The lattice elements are the elements of a discrete space. For the practical purposes of this article, we can indifferently decide for any of these options. However, for reasons to do with the accelerated expansion of space, with the quantisation of gravity and to keep the future development of the theory somewhat compatible with general relativity, I will defend here the second option, that is, that the lattice elements are the isolated elements of a discrete space.

Note that, if Plancks oscillators are the elements of a discrete space, then the meaning of expression (11) is far from innocent or trivial, since it relates the energy density of space with its geometry (the distance i between the lattice cells elements from which space is formed). The length of any line element in this space is (due to the simple cubic lattice geometric orthogonal characteristics (Liang-fu Lou, 2003)):

$$\Delta x = \Delta y = \Delta z = i \tag{12}$$

Since Planks law is a distribution, this necessarily represents a distribution of nested lattice cells. It is clear that the lattice elements cannot have a radius r=λ/2=i/2. I will consider that they are point like entities. and, in that case, some repulsive force must be keeping them apart. In fact, the lattice structure would not be stable in the absence of a repulsive force connecting its elements. An attractive force would result in the collapse of that structure. Planck's oscillators have a total energy of:

$$E = \hbar w \tag{13}$$

This energy has always been considered fully kinetic and, consequently, the oscillators non-interacting. However, we are now taken to the possibility that a fraction of this energy might be in the form of a potential energy. Let K

be the fraction of potential energy Ep and (1-K) the fraction of kinetic energy E_k, of any one oscillator. We would have (from (11) and (13)):

$$E_p = K\hbar w = K\frac{2\pi c\hbar}{i} \tag{14}$$

$$E_k = (1-K)\,\hbar w = (1-K)\frac{2\pi c\hbar}{i} \tag{15}$$

If we now locate an orthogonal coordinate system aligned with one of the lattice axis and consider that the minimum length line element is Δx=i, the force between any two elements in any of the three dimensions of space would be:

$$F = \frac{dE_p}{dx} \simeq \frac{E_p}{i} = -K\frac{2\pi c\hbar}{i^2} \tag{16}$$

To determine the value of the constant K, let us imagine the hypothetical sudden appearance of one additional oscillator, excited with the wavelength i, in the middle of a lattice characterised by an average wavelength iv, as in Figure 1.

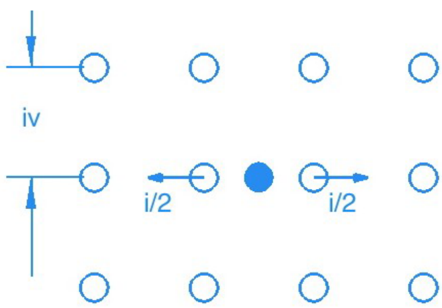

Figure 1. The hypothetical creation of one additional element in the lattice

If there is a repulsive force (16) between the elements, the new element would have to push the other elements apart, in a perfect equilibrium situation, *i/2* to each side. Let us consider this displacement as a perturbation to the oscillators equilibrium positions. The action involved in this is:

$$S = \int_{t_1}^{t_2} E_p dt \simeq F^* \Delta x \Delta t \tag{17}$$

The force F* exerted on the new oscillator by its closest neighbours, at the left and right of the new oscillator, is (from (16)):

$$F^* = \left(-K\frac{2\pi c\hbar}{\left(i_v - \frac{i}{2}\right)^2}\right) + \left(-K\frac{2\pi c\hbar}{\left(-i_v + \frac{i}{2}\right)^2}\right) \tag{18}$$

If we consider that the force propagates at the speed c, then the time necessary for it to reach the closest neighbour is:

$$\Delta t = \frac{i_v - \frac{i}{2}}{c} \tag{19}$$

and the maximum displacement allowed in this period of time is:

$$\Delta x = i_v - \frac{i}{2} \tag{20}$$

The action (17) becomes:

$$S = \frac{16\pi\hbar K\left(i_v - \frac{i}{2}\right)^2}{(i - 2i_v)^2} \tag{21}$$

The numerical value of this expression is not affected by the value of i or iv , so we can make i=0 to obtain:

$$S = 4\pi K\hbar = 2Kh \tag{22}$$

which equals Planck's constant in the case $K=1/2$. With this expression I prove two different things. One one side that Plancks oscilators energy is not purely kinetic and, on the other hand, that the root cause of Planck constant can be found with purely classical mechanics arguments. Since K is the fraction of potential energy, we have that each element has its total energy equally partitioned between potential and kinetic. In average (from (14) and (15)) we have:

$$E_p = \frac{\hbar w}{2} = \frac{\pi c\hbar}{i} \tag{23}$$

$$E_k = \frac{\hbar w}{2} = \frac{\pi c\hbar}{i} \tag{24}$$

and the average force connecting any two elements of the discrete space becomes:

$$F = \frac{\partial E_p}{\partial x} = -\frac{\pi c\hbar}{i^2} \tag{25}$$

We have then a discrete space which is host to a potential vector and force field. Since bodies exist in space, this force has to apply between any body and the neighbouring discrete elements of space. It results that this force has to be conservative, otherwise Newtons third law would not hold in the free space.

3. Proving De Broglie Conjecture $E = mc^2 = h\nu$

Given that the elements of the discrete space are connected to each other by force (25), it follows that it makes more sense if light is the result of a perturbation to one of its elements propagating throughout the others. Let us imagine one dimension of the tridimensional lattice made out of the elements as shown in Figure 2.

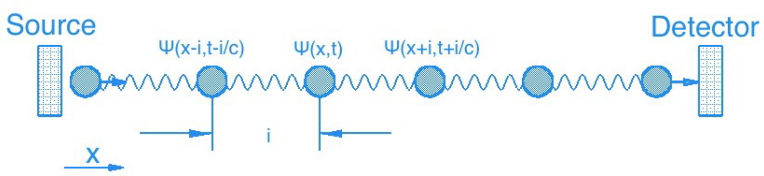

Figure 2. Energy propagation on the lattice by a perturbation of an element at the source. The spring symbol connecting the elements represents (25)

Let us consider the simplified situation in which all space elements are in their equilibrium positions and one of them, at the source, suffers a perturbation in the X direction and see if a wave will eventually propagate throughout the lattice. The detection of a photon as a point on a detector screen will correspond to the interaction of the closest excited space element with that same screen. Note that the space element that excites the screen is not the same that suffered the original perturbation at the source. Let us then model what happens when one of our space elements suffers from a perturbation to its original position, Δ x= ψ (x,t), in the X direction. ψ (x,t) will then be the time-dependent function that describes the dynamics of the space elements and the eventual wave in one dimension of space. Considering the closest neighbour approximation, the force exerted on the element at x=ni (with n integer), suffering a perturbation ψ(x,t) is (from (25)):

$$F = \left(-\left(-\frac{\pi c\hbar}{(i + \psi(x,t))^2)}\right) + \left(-\frac{\pi c\hbar}{(i - \psi(x,t))^2)}\right)\right) \tag{26}$$

where we consider the increase or decrease of the distance to the closest neighbours at the left and right of the element under study. Let us now artificially multiply ψ(x,t) in the denominator by a unitary factor *i/i*:

$$F = \left(-\left(-\frac{\pi c\hbar}{(i + i\frac{\psi(x,t)}{i})^2)}\right) + \left(-\frac{\pi c\hbar}{(i - i\frac{\psi(x,t)}{i})^2)}\right)\right) \tag{27}$$

Remembering that *i* is the minimum length of a line element, $\Delta x = i$, we can write:

$$F = \left(-\left(-\frac{\pi c\hbar}{(i + i\frac{\partial\psi(x,t)}{\partial x})^2)}\right) + \left(-\frac{\pi c\hbar}{(i - i\frac{\partial\psi(x,t)}{\partial x})^2)}\right)\right) \tag{28}$$

If *m(x,t)* is the element mass and assuming that Newtons second law holds, we have:

$$F = \left(-\left(-\frac{\pi c\hbar}{(i + i\frac{\partial\psi(x,t)}{\partial x})^2)}\right) + \left(-\frac{\pi c\hbar}{(i - i\frac{\partial\psi(x,t)}{\partial x})^2)}\right)\right) = m(x,t)\frac{\partial^2\psi(x,t)}{\partial t^2} \tag{29}$$

The solution to this differential equation, when we make the mass to vanish, is:

$$\psi[x,t] = \frac{\pi c}{4w}\operatorname{csch}^4\left(\frac{\pi}{2}\right)(\cosh(\pi)\operatorname{sech}(tw - \frac{wx}{c} + A) - 1)^2 \tag{30}$$

A can be determined with the boundary condition that at *x=0* (the source) and *t=0* (the time origin of the pulse), ψ(x,t) must be null. This results in:

$$\psi[x,t] = \frac{\pi c}{4w}\operatorname{csch}^4\left(\frac{\pi}{2}\right)(\cosh(\pi)\operatorname{sech}(tw - \frac{wx}{c} - \pi) - 1)^2 \tag{31}$$

Expressed as function of a phase angle:

$$\phi = \frac{w}{c}x - wt \tag{32}$$

it becomes:

$$\psi[\phi] = \frac{\pi c}{4w}\operatorname{csch}^4\left(\frac{\pi}{2}\right)(\cosh(\pi)\operatorname{sech}(\phi - \pi) - 1)^2 \tag{33}$$

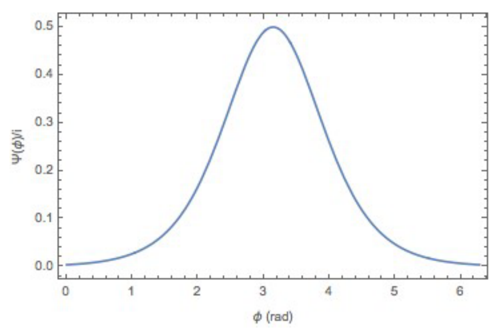

Figure 3. Wave equation normalised by *i*

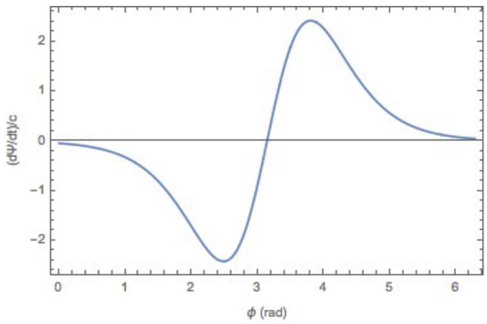

Figure 4. Element speed normalised by c

Note that (31) and (33) are real valued functions. Plotting this function, we can see that any one particular element (initially in the equilibrium position), moves in the x direction until its speed reduces to zero and then returns to its original equilibrium position where it's speed once again reduces to zero. The element average velocity is zero, although its average speed is c. For the average oscillator speed to be c, in some moments in time it exceeds it, as can be seen in figure 4. However, I must point out that the special theory of relativity was derived from macroscopic mechanical considerations and that its solutions might represent only an average of some mechanism, of which the one derived here is one possible example. It is possible to use (31) to deduce lights dispersion relation and explain the Crab pulsar dispersion phenomenon in the entire range of measured frequencies (Neto, 2016). We need now to prove that our elements of the discrete space have a non-vanishing mass. Since the average velocity of each element is zero, there is no objection to this possibility. We can determine each element mass by writing the Hamiltonian:

$$E = E_k + E_p \tag{34}$$

where E_p is the potential energy and E_k the kinetic energy of the excited element. The potential energy, considering Newtons second law, can be written:

$$E_p = \int F dx = \int m \frac{d^2\psi}{dt^2} dx + V_0 \tag{35}$$

where V_0 is the integration constant that will correspond to a certain ground potential energy. This ground potential will exist when the oscillators are not excited, that is, when their kinetic energy is null, so we can assume this ground potential to be equal to:

$$V_0 = m_0 c^2 \tag{36}$$

where m_0 would be the oscillator mass at rest. We can use the relativistic expression for the mass at a different speed to be:

$$m_0 = m\sqrt{1 - \frac{\left(\frac{d\psi}{dt}\right)^2}{c^2}} \tag{37}$$

and for the corresponding element kinetic energy:

$$E_k = \frac{m_0 c^2}{\sqrt{1 - \frac{\left(\frac{d\psi}{dt}\right)^2}{c^2}}} - m_0 c^2 \tag{38}$$

From (35) to (38) and solving for E_p , E_k and m_0, we obtain (after replacing the results by the phase angle (32)) the resulting total oscillator or element energy:

$$E = \frac{1}{4}c^2 m\left(\pi\cosh(\pi)\operatorname{csch}^4\left(\frac{\pi}{2}\right)\operatorname{sech}^3(\phi-\pi)\left(2\sinh\left(\frac{\phi}{2}\right)\cosh\left(\frac{3\phi}{2}-2\pi\right)-\sinh(\phi)\right)+4\right) \tag{39}$$

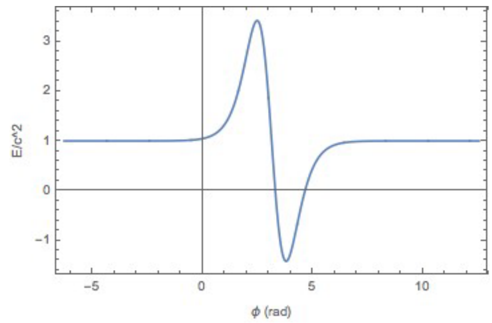

Figure 5. Time dependent element energy (39) for m=1/c^2. Note the non vanishing ground potential

The average of (39) is:

$$\overline{E} = \frac{1}{2\pi}\int_0^{2\pi} E d\phi = \bar{m}c^2 \tag{40}$$

We arrive at the conclusion that $E = mc^2$ does not only applies to matter, but also to radiation. More exactly, it is a relation that describes a property of space. Necessarily and by extension, it is a relation that applies to all physical entities, for the simple reason that all physical entities exist in space.

The expression of force (25) was obtained from Planck's law, in which every space element is a Planck's oscillator with total energy (13). Since the pulse described by (31) is limited to the extension occupied by one single space element, then each excited space element will have one quantum total energy. We have then:

$$\overline{E} = \bar{m}c^2 = \bar{\hbar}w \tag{41}$$

which was De Broglies hypothesis, which I now finally consider proved in this context and from which results the expression that defines the discrete space elements mass.

Do the elements of the discrete space have also a ground potential energy similar to the quantum harmonic oscillator? We will now see that the answer is affirmative and that the expression of this ground energy, being different and a prediction of this theory, can eventually be used for its experimental validation or disproval. The situation we have described is an idealised situation which represents the propagation of one quantum in a lattice characterised by the same average average frequency. However, if we take the limit of the first term of expression (35) when x tends to infinity (for *t=0*), we find that the potential vanishes.

$$\lim_{\substack{x\to\infty \\ x\to 0}} E_p = \lim_{x\to\infty}\int m\frac{d^2\psi}{dt^2}dx = 0 \tag{42}$$

Since in the universe the CMB radiation is ubiquitous, in the limit we should have a potential which should equal the average potential energy of that CMB radiation, that is (see (23)):

$$V_0 = \frac{1}{2}\hbar w_v \bar{m}_0 = \frac{\hbar w_v}{2c^2} \tag{43}$$

where w_v is the average frequency of the vacuum/CMB radiation, which we will quantify further on. For the energy of any arbitrary element, and considering this ubiquitous CMB component, one should then write, not (13), but:

$$\overline{E} = \hbar\left(w + \frac{1}{2}w_v\right) \tag{44}$$

were w_v represents an external energy source, being the word external a reference to the elements in the close vicinity of any element under consideration (note the difference to the usual expression of the quantum harmonic oscillator).

Another important point is to show that the theory is also compatible with Heisenbergy uncertainty principle. If we consider its original form:

$$\Delta x \Delta mv \geq h \tag{45}$$

and noting that the smallest possible line element in the discrete space is Δ x=i and (41) with (11) and expanding (45), we obtain:

$$i\frac{\hbar w}{c^2}c \geq h \Rightarrow \frac{2\pi c}{w}\frac{\hbar w}{c^2}c \geq h \Rightarrow h \geq h \tag{46}$$

where only the equality is true. If however we consider (44) and repeating the exercise, we have:

$$h(1 + \frac{1}{2}\frac{w_v}{w}) \geq h \tag{47}$$

which is always true and establishes the CMB as the external source of the ground or zero point energy.

4. Quantifying i, the Cosmological Constant and the Parameter w of the Equation of State

If the elements of the lattice are connected through the repulsive force (25) then they will tend to an accelerated expansion if in the absence of a reaction force. The pressure in each lattice cell area element is:

$$P = \frac{F}{A} = \frac{-\frac{\pi c\hbar}{i_v{}^2}}{i_v{}^2} = -\frac{\pi c\hbar}{i_v{}^4} \tag{48}$$

which is a negative pressure, as required by a cosmological constant. We can easily find the average distance between the elements of our discrete space, i, by using Planck's law for the energy density:

$$\rho_v = \int_0^\infty \frac{8\pi h\upsilon^3}{c^3}\frac{1}{e^{\frac{h\upsilon}{k_b T_v}} - 1}\partial\upsilon = \frac{\pi^2 k_b{}^4 T_v{}^4}{15c^3\hbar^3} \tag{49}$$

Remembering that the volume packing fraction of the simple cubic lattice type is $\pi/6$, the density of elements (number of excited elements in one cubic meter) of excited oscillators in the lattice is (see (4)):

$$\rho = \frac{\pi}{6}\frac{1}{i_v{}^3} \tag{50}$$

Since each space element is a Planck's oscillator, then each element has one quantum total energy:

$$E_t = \hbar w = \frac{2\pi c\hbar}{i_v} \tag{51}$$

The average energy density of the vacuum is then:

$$\rho_e = \frac{\pi}{6i_v{}^3}\frac{2\pi c\hbar}{i_v} = \frac{\pi^2 c\hbar}{3i_v{}^4} \tag{52}$$

This last expression must equal (49). Solving for i_v we obtain:

$$i_v = \frac{2\pi c}{w_v} = \frac{5^{1/4} c\hbar}{k_b T_v} \tag{53}$$

or:

$$\rho_e = \frac{\pi}{6{i_v}^3}\frac{2\pi c\hbar}{i_v} = \frac{\pi^2 c\hbar}{3{i_v}^4} = 4.2x10^{-14} Jm^{-3} \tag{54}$$

The cosmological constant can now be directly calculated from (54):

$$\Lambda = 8\pi\frac{G}{c^4}\rho_e = 8\pi\frac{G}{c^4}\frac{\pi^2 c\hbar}{3{i_v}^4} = \frac{8\pi^3 G{k_b}^4{T_v}^4}{15c^7\hbar^3} = 8.663x10^{-57} m^{-2} \tag{55}$$

which is a function of time in a cosmological timescale, since it is a function of the vacuum temperature T_v. We can repeat the statement by finding the value of the parameter w of the equation of state, i.e., the relation between the pressure (48) and the energy density (52):

$$w = \frac{P}{\rho_e} = -\frac{3}{\pi} = -0.954930 \tag{56}$$

which is independent of any physical parameter. The expectation of this value resulting from supernova observations ranges between w=-0.969 (+0.059/-0.063 stat ; +0.063/-0.066 sys) (Kowalski & Rubin, 2008) to w=-1.02 (+0.055/-0.055) (Betoule et al.,2014). We have then a special form of slow-rolling potential, although here resulting from a vector potential field rather then a scalar one. On the other hand, the average mass density of the discrete space is:

$$\rho_m = \frac{1}{c^2}\rho_e = \frac{\pi^2 c\hbar}{3{i_v}^4} = \frac{8\pi^5{k_b}^4 T^4}{15c^5 h^3} = 4.6x10^{-31} Kgm^{-3} \tag{57}$$

which is also the expected value of the dark matter density in our galaxy(Garbari, Read & Lake, 2011).

5. Discussion

By interpreting Plancks law as describing the energy content of the elements of a discreet space, we can see that the calculation of the energy and mass density of space is a trivial matter. On the other hand, I have shown an alternative solution for the mechanism of propagation of light that resolves the paradox of light as a photon, having a non-vanishing effective mass and at the same time propagating at the speed of light. With the described model, one can in fact eliminate the word effective. For the photon mass, the energy and mass density of this discrete space have similar magnitude to the expected values of the vacuum energy density and of the density of dark matter in our galaxy, so it is possible to propose that these last are properties of space itself. One as to note however, that those values are function of time in a cosmological scale as well as necessarily dependent of the location. There will be energy density local distributions due to the radiation emitted from matter, which increases the local temperature above the CMB temperature. It is then not surprising to find dark matter density to be higher in locations with high matter concentration. Likewise, the cosmological constant value is not only a global parameter, but should also have higher values in those same regions. It seems however that I have introduced a fifth force (or sixth, if one counts with De Broglie fifth force). However, I plan to show in future articles how the four fundamental forces can be shown to be direct expressions of (25), without any need of additional constants or parameters. In fact, one just needs to note that the magnitude of (25) is a function of the local energy density. Other important connected issues have also a trivial explanation within the context of the theory. Since (25) connects all the elements of the discrete space, then the entire universe is connected throughout the free space, which is a direct and quantifiable expression of Machs principle. Regarding the horizon and flatness problems, it is clear that they have here also self-evident solutions. In fact, if the law (25) applies at every point in space, then all regions of space will evolve with time in a similar way, independently if they are connected or disconnected. The flatness of space results directly from the orthogonal characteristics of the lattice (Liang-fu Lou, 2003). Note that the precise mapping of the universe shape can be made by the measurement of its temperature distribution, since this variable is directly related to the geometry of space through (53).

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