Calculation of the Speed Quantum and of the Speed Limit of Objects

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Because of Einstein's theory of relativity [2,3], *it is generally admitted that the speed limit of an object is the speed of light in vacuum. However, it cannot be the case since a mass that travels at the speed of light would have, according to the equations of relativity, an infinite mass* [4]. *Since the apparent mass of the universe is finite* [5,6], *it becomes impossible to transfer to an object more energy than there is in the whole universe. So, there must be a speed limit that is less than the speed of light for all objects. According to our calculations, the difference between the speed of light and the speed limit of objects would be what we call a speed quantum. This speed quantum would be about* 2.34×10^{-114}*m/s.*

KEY WORDS: Quantum, speed limit, relativity, Einstein, Planck

1. INTRODUCTION

To calculate the value of the speed quantum and the speed limit of objects, we will begin by calculating the number N that represents the maximum number of photons that can be present in the whole universe. This will allow us to locate the Planck mass on the mass scale between the smallest mass, which is associated with the photon, and the biggest mass, the mass of the universe. Seeing, by calculation, that the Planck mass is located in a very particular place in the mass scale and by making a few hypotheses on the special relativity equations, we will be able to calculate the speed limit of objects and the value of the speed quantum. We will then be able to make a small analysis of the potential consequences on particles and on agglomeration of particles (atoms and objects).

2. DEVELOPMENT

2.1. Calculation of the Number N

Let's start by calculating the number N which corresponds to the number of particles having the smallest quantity of energy.

The energy of a photon is given by:

$$E = \frac{h \cdot c}{\lambda} \quad \textbf{(1)}$$

In this equation, $h \approx 6.62606957 \times 10^{-34}$ J·s is the Planck constant [7], $c \approx 2.99792458$ m/s is the actual speed of light in vacuum [7] and λ is the wavelength.

Theoretically, the photon which has the smallest quantity of energy is the one that has the greatest wavelength. There is no greater wavelength than the circumference of the universe.

We define the apparent radius of curvature R_u of the luminous universe as being the distance that light traveled with a delay equivalent to the apparent age of the universe t_u :

$$R_u = c \cdot t_u = \frac{c}{H_0} \approx 1.29 \times 10^{26} \text{m} \quad \textbf{(2)}$$

The apparent age of the universe is given by the following equation [9]:

$$t_u = \frac{1}{H_0} \approx 13.7 \times 10^9 \text{ years} \quad \textbf{(3)}$$

H_0 represents the Hubble constant. We will use the value obtained by David Rapetti's works [1]:

$$H_0 = 71.5 \pm 1.3 \frac{\text{km}}{\text{s} \cdot \text{MParsec}} \quad \textbf{(4)}$$

This value is also in agreement with the value of $H_0 \approx 70.4 \pm 1.4$ km/(s·MParsec) measured by the WMAP team after seven years of observation [12] and by our own researches [8].

So this photon would have the following energy:

$$E = \frac{h \cdot c}{2 \cdot \pi \cdot R_u} = \frac{h \cdot H_0}{2 \cdot \pi} \approx 2.44 \times 10^{-52} \text{Joule} \quad \textbf{(5)}$$

Let's associate a mass m to this energy by using the following equation of the special relativity [2]:

$$E = m \cdot c^2 \quad \textbf{(6)}$$

With the equations **(5)** and **(6)**, we get:

$$m_{ph} = \frac{h}{2 \cdot \pi \cdot R_u \cdot c} \approx 2.72 \times 10^{-69} \text{k}g \quad \textbf{(7)}$$

The mass m_{ph} is a mass associated with a photon having a wavelength of $2 \cdot \pi \cdot R_u$ (where R_u is the radius of the apparent radius of curvature of the universe). This mass is the smallest unit of mass. Since the apparent radius of curvature of the universe always increases because of the expanding universe [11], this mass is supposed to diminish over time.

On the other hand, the biggest mass being would be the apparent mass of the universe m_u. This mass is given by the following equation [5,6] :

$$m_u = \frac{c^3}{G \cdot H_0} \approx 1.74 \times 10^{53} \text{kg} \tag{8}$$

Here, G represents the universal gravitational constant [7] which is about $6.67384 \times 10^{-11} \text{m}^3/(\text{kg} \cdot \text{s}^2)$.

We could obtain the maximum number of photons of wavelength $2 \cdot \pi \cdot R_u$ contained in the universe by dividing the apparent mass of the universe m_u by the mass m_{ph}. Furthermore, without doing the demonstration, here are some equalities which may be easily demonstrated:

$$N = \frac{m_u}{m_{ph}} = \frac{m_u^2}{m_p^2} = \frac{m_p^2}{m_{ph}^2} = \frac{R_u^2}{L_p^2} = \frac{1}{t_p^2 \cdot H_0^2} \approx 6.41 \times 10^{121} \tag{9}$$

The Planck units are defined as following:

The Planck mass: $$m_p = \sqrt{\frac{h \cdot c}{2 \cdot \pi \cdot G}} \approx 2.17651 \times 10^{-8} kg \tag{10}$$

The Planck length: $$L_p = \sqrt{\frac{h \cdot G}{2 \cdot \pi \cdot c^3}} \approx 1.61699 \times 10^{-35} \text{m} \tag{11}$$

The Planck time: $$t_p = \sqrt{\frac{h \cdot G}{2 \cdot \pi \cdot c^5}} \approx 5.39106 \times 10^{-49} \text{s} \tag{12}$$

We can have N appearing in a multitude of equations. It represents the maximum of photons of wavelength $2 \cdot \pi \cdot R_u$ constituting the universe.

Without entering into details, let's note that the three following numbers are approximately equal to those that Paul Dirac has shown in his large numbers hypothesis in 1974 [10]. Without doing all the demonstrations, we also observe that these three large numbers seem approximately in agreement with certain realities that are well tangible.

$N^{1/3} \approx 4.00 \times 10^{40} \approx$ Ratio between the electrostatic energy and the gravitational energy in an electron **(13)**

$N^{2/3} \approx 1.60 \times 10^{81} \approx$ Number of protons in the universe **(14)**

$N^{3/3} \approx 6.41 \times 10^{121} \approx$ Maximum number of photons of wavelength $2 \cdot \pi \cdot N$ in the universe **(15)**

We notice that the only large number which seems to govern all the others is N.

2.2. Position of the Planck Mass in the Scale of Masses

An interesting question would be to find out what should be the geometrical average between the largest mass (the apparent mass of the universe m_u) and the smallest mass (the mass of a photon of wavelength $2 \cdot \pi \cdot R_u$).

Using the equations **(7)**, **(8)** and **(10)**, we notice that the geometrical average between two masses is given by:

$$\text{Geometrical average} = \sqrt{m_u \cdot m_{ph}} = \sqrt{\frac{h \cdot c}{2 \cdot \pi \cdot G}} = m_p \quad \textbf{(16)}$$

We notice that the mass corresponds exactly to the Planck mass. Therefore, the value of that mass is not just a coincidence.

The Planck mass also corresponds to the highest level of energy that a particle rotating on itself can reach since the heavier is the particle, the smaller is the rotating radius. In the case of the Planck mass, that radius is the Planck length which corresponds to a quantum of length. It is not possible to spin faster since the radius is at its minimum.

The energy E_p contained in the Planck mass may be seen as a particle having the energy $E_p = m_p \cdot c^2$. It may also be seen as a wave (a vector rotating at the speed of light) $\lambda = 2 \cdot \pi \cdot L_p$ using the equation **(1)**. Let's note that the Planck length L_p in the calculation of the wavelength corresponds to the smallest radius of a confined particle. Consequently, this also corresponds to a particle having the highest energy. As explained in the preceding paragraph, it is IMPOSSIBLE to have a particle that would have more energy than the Planck mass.

$$E_p = m_p \cdot c^2 = \frac{h \cdot c}{2 \cdot \pi \cdot L_p} \quad \textbf{(17)}$$

Using the equations **(11)** and **(17)**, we obtain the equation **(10)** which is the definition of the Planck mass.

2.3. Calculation of the Speed Quantum

According to the special relativity of Einstein [2], if we take a mass m_0 at rest and we make it move at a speed v, its mass in movement m will be:

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \quad \textbf{(18)}$$

The problem with this equation is that it lets us suppose that it is possible to reach an infinite value for m when we make v tending to reach c. A priori, our logical sense would tell us that it is impossible to reach a mass superior to the one of the universe.

To solve the problem, we think that v is limited by physical conditions. Since the Planck mass represents the highest level of energy, we could calculate the speed at which we might move a particle having the mass associated to a photon of wavelength $2\cdot\pi\cdot R_u$ and so get the Planck mass m_p.

$$\frac{m_{ph}}{\sqrt{1-\frac{v_{\max}^2}{c^2}}} = m_p \quad \textbf{(19)}$$

Let's isolate $v_{\max}$ in the equation (19) to get:

$$v_{\max} = c\cdot\sqrt{1-\frac{m_{ph}^2}{m_p^2}} \quad \textbf{(20)}$$

Since $m_{ph} << m_p$, we can make the following approximation:

$$v_{\max} \approx c\cdot\left(1-\frac{m_{ph}^2}{2\cdot m_p^2}\right) = c-\frac{c}{2\cdot N} \quad \textbf{(21)}$$

If we replace $v_{\max}$ by c-ε_v, the value of ε_v could be defined as being a speed quantum.

$$\varepsilon_v = \frac{c}{2\cdot N} \approx 2.34\times 10^{-114}\text{m/s} \quad \textbf{(22)}$$

That speed variation is the smallest speed unit possible. To take better into account the physical limitations imposed by the universe, we suggest to rewrite the equation **(18)** as:

following: $m = \dfrac{m_0}{\sqrt{1 - \dfrac{(c - n \cdot \varepsilon_v)^2}{c^2}}}$ where n = 1, 2, 3, … (2·N) **(23)**

In a general way, the Lorentz factor applied to the relativistic equations of energy, momentum and masses should be written as follows:

$$\sqrt{1 - \frac{(c - n \cdot \varepsilon_v)^2}{c^2}} \quad \text{where n = 1, 2, 3, … } (2 \cdot N) \tag{24}$$

Be careful, *n* can go down to 1 only in the case when we want to accelerate photons of wavelength $2 \cdot \pi \cdot R_u$. The number *n* cannot equal 0. But this number increases as the mass m_0 increases. It is a directly proportional ratio. In fact, the minimum value of *n* is n_{min}:

$$n_{\min} = 2N \cdot \frac{m_0}{m_p} \tag{25}$$

3. CONSEQUENCES OF OUR RESULTS

3.1. In Terms of the Particle

A single elementary particle must necessarily have a smaller mass than the Planck mass, whatever its speed. The more the speed of the particle approaches the speed of light in vacuum *c*, the more its mass approaches the Planck mass. Its ultimate speed is $c - \varepsilon_v$.

3.2. In Terms of Particle Agglomerations

An agglomeration of individual particles can be an atom or a complex agglomeration of atoms.

In specific cases, as every elementary particle cannot exceed the Planck mass, the boundary of the agglomeration rate is limited by the mass of the most massive component of the said particle agglomeration. If a higher speed is reached, the lighter particles will dissociate from the agglomeration. The heavier particles would ionize and lose their electrostatic and nuclear cohesion.

4. CONCLUSION

Based on our calculations, we conclude that the maximum velocity of particles and objects is not the speed of light but c - ε_v . There would not be enough energy in the whole universe to reach the speed *c*. This is true even for a photon. In fact, the moving mass of a particle cannot exceed the Planck mass. This is why the maximal speed of a particle is limited by its mass at rest. The bigger it is, the less will be its ability to increase in speed.

The mass of atoms and objects is linked to the particles that constitute them. If we want to preserve the cohesion of objects, we must respect the maximum speed of the most massive particles constituting each object. Furthermore, the total mass of an object is the sum of the particle masses constituting the moving object.

This document will perhaps enable us to find the theoretical limits that large colliders can reach.

5. REFERENCES

[1] Rapetti, David and al., "A Combined Measurement of Cosmic Growth and Expansion from Clusters of Galaxies, the CMB and Galaxy Clustering", *Mon. Not. R. Astron. Soc.*, filed May 22nd 2012, pp 1-10, arXiv:1205.4679v1 [astro-ph.CO]

[2] Einstein, Albert, “La relativité”**,** *Petite Bibliothèque Payot***,** v. 25, Paris, original 1956 version from Gauthier-Villar integrally used by the Payot & Rivages editions for the 2001 version, 219 p.

[3] Einstein, Albert, "The Foundation of the General Theory of Relativity", *The Principle of Relativity (Dover Books on Physics)*, New York, publications Dover, 1952 (original 1916 paper), pp. 109-164.

[4] Einstein, Albert, "On the Electrodynamics of Moving Bodies ", *The Principle of Relativity (Dover Books on Physics)*, New York, Dover publications, 1952 (original 1905 paper), pp. 35-65.

[5] Carvalho, Joel C., "Derivation of the Mass of the Observable Universe", *International Journal of Theoretical Physics*, v. 34, no 12, December 1995, p. 2507.

[6] Mercier, Claude, "Calculation of the Apparent Mass of the Universe", *Pragtec*, Baie-Comeau, Québec, Canada, May 5th 2012, paper available on Internet at: www.pragtec.com/physique/

[7] "Latest (2010) Values of the Constants", NIST Standard Reference Database 121, last update: April 2012, paper available on Internet at: http://physics.nist.gov/cuu/Constants/index.html

[8] Mercier, Claude, "Calculation of the Average Temperature of the Cosmic Microwave Background of the Universe and of the Hubble Constant", *Pragtec*, Baie-Comeau, Québec, Canada, July 9th 2012, paper available on Internet at: www.pragtec.com/physique/

[9] Mercier, Claude, "Calculation of the Age of the Universe", *Pragtec*, Baie-Comeau, Québec, Canada, April 11th 2012, paper available on Internet at: www.pragtec.com/physique/

[10] Dirac, P. A., "Cosmological Models and the Large Number Hypothesis", *Proceeding of the Royal Society of London*, England, 1974, A338 (1615): pp. 439-446.

[11] Hubble, E. and Humason, M. L., "The Velocity-Distance Relation among Extra-Galactic Nebulae", *The Astrophysical Journal*, v. 74, 1931, p.43.

[12] Jarosik, N. and al., "Seven-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Sky Maps, Systematic Errors, and Basic Results", *The Astrophysical Journal Supplement Series*, v. 192, no 2, February 2011, pp. 1-15.