# Shift of the Electromagnetic Spectrum over Time

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Rev. October 17th, 2015

*In 1929, Edwin Powell Hubble found, by observation of galaxies, that the universe was expanding. The galaxies, regardless of their own movements, fled each other to even greater speeds when they were far from each other* [1].

*Today, astrophysicists accurately measure the relative remoteness speeds of the different galaxies using the Doppler effect. A redshift of the optical spectrum of stars means that they are moving away from us. On the contrary, a blueshift of the same spectrum means that they approach us.*

*In this work, we show that the entire electromagnetic spectrum undergoes a shift towards larger wavelengths and that, whatever the wavelength and whatever the direction of the relative movements of different galaxies. This phenomenon is directly related to the expansion of the universe and the fact that light accelerates over time. Moreover, this phenomenon may seem undetectable due to the fact that the wavelengths are always taken with respect to the wavelengths emitted by our own Sun or other terrestrial light sources that we use as a reference. In addition, we will see that even the mechanical standards lengths can not be used to measure this shift since these same standards lengths are affected by the expansion of the universe. For now, only variations from the reference spectrum can be detected (by Doppler effect).*

*Since the frequency of the photons remain stable over time despite the acceleration of the light and despite the shift of the electromagnetic spectrum over time, it seems possible to build a clock that stays stable over time which is not influenced by the change of the refractive index of the vacuum, provided that it is only based on the oscillation frequency of the photon.*

**KEY WORDS:** Photon, redshift, electromagnetic spectrum

## 1. INTRODUCTION

The universe is expanding [1]. Currently, astrophysicists can see it using the Doppler effect due to the redshift of the light spectrum of the galaxies around us which can be interpreted as a remoteness of them with respect to us.

But it seems that it is not only the lengths of electromagnetic waves of galaxies that are receding from us that increase over time, but the wavelength of all the photons in the universe. This phenomenon adds to the redshift of the Doppler effect, but as our long reference sources vary over time at the same rate, this phenomenon may seem undetectable.

We will begin by recalling some results from previous work to define more precisely some useful parameters before setting our basic assumptions. Then, we will see why the electromagnetic spectrum seems forced to slowly shift to larger wavelengths.

## 2. VALUES OF SOME USEFUL PARAMETERS

### 2.1. Theoretical Hubble Constant $H_0$ Coming from Previous Works

In previous work [2], we have already shown that the Hubble constant $H_0$ could be expressed by an equation whose accuracy was dependent on the speed of light $c$, the fine structure constant $\alpha$ and the classical radius of electron $r_e$.

$$H_0 = \frac{c \cdot \alpha^{19} \cdot \beta^{1/2}}{r_e} \tag{1}$$

$$H_0 \approx 72.09548632 \pm 0.00000046 \text{ km/}(\text{s} \cdot \text{MParsec}) \tag{2}$$

According to the CODATA 2010 [3]:

- Actual speed of light in the vacuum $c \approx 299792458$ m/s
- Fine structure constant $\alpha \approx 7.2973525698 \pm 0.0000000024 \times 10^{-3}$
- Classical electron radius $r_e \approx 2.8179403267 \pm 0.0000000027 \times 10^{-15}$ m

The value of $\beta$ is an irrational number. It represents the ratio of the expansion rate of the material universe and the speed of light in vacuum $c$ [4]:

$$\beta = 3 - \sqrt{5} \approx 0.764 \tag{3}$$

The value of the Hubble constant $H_0$ obtained in **(14)** is consistent with that of Wang Xiaofeng and his team [5] who obtained the following measure: $H_0 = 72.1 \pm 0.9$ km/(s·MParsec). So, we will use our equation in this document to describe the Hubble constant $H_0$.

### 2.2. Theoretical Universal Gravitational Constant $G$ from Previous Works

In previous work [2], we have already shown that the constant of universal gravitation $G$ can be described with high accuracy using the following equation that depends primarily on the constant of fine structure $\alpha$, the classical radius of the electron $r_e$ , its mass $m_e$ and the speed of light in vacuum $c$:

$$G = \frac{c^2 \cdot r_e \cdot \alpha^{20}}{m_e \cdot \beta} \approx 6.67323036 \pm 0.0000003 \times 10^{-11}\ \mathrm{m}^3/\left(kg \cdot s^2\right) \tag{4}$$

According to the CODATA 2010 [3]:

- Universal gravitational constant $G \approx 6.67384 \pm 0{,}00080 \times 10^{-11}\ \mathrm{m^3/(kg \cdot s^2)}$
- Rest mass of the electron $m_e \approx 9.10938291 \pm 0{,}00000040 \times 10^{-31}$ kg.

Since the value obtained in **(4)** is consistent with the error margin of the CODATA 2010, we will use this value in this document to describe the universal gravitational constant *G*.

### 2.3. Number *N* of Dirac

In 1974, Dirac made the assumption that some big numbers were consistently coming back when we were doing the ratio of some numbers [6]. We have established that all these numbers actually came from a single number *N* that is of the order of $10^{121}$ [7]. By applying different rational exponents to *N* (e.g. ½, ⅓, etc.), we get numbers that have the same order of magnitude as all the large numbers of the original hypothesis of Dirac.

In previous work [7], we showed that if we associate a mass $m_{ph}$ to photons that have a wavelength equal to the apparent circumference of the universe (i.e. $2 \cdot \pi \cdot R_u$), the number *N* then corresponded to the maximum number of these photons that may exist in our universe which has the apparent mass $m_u$.

The mass associated to a photon of wavelength $2 \cdot \pi \cdot R_u$ (apparent circumference of the universe) is given by $m_{ph}$ [7]:

$$m_{ph} = \frac{h}{2 \cdot \pi \cdot R_u \cdot c} = \frac{h \cdot H_0}{2 \cdot \pi \cdot c^2} \approx 2.74 \times 10^{-69}\,\mathrm{kg} \tag{5}$$

According to the CODATA 2010 [3], the Planck constant is $h \approx 6.62606957 \times 10^{-34}$ J·s.

The apparent mass of the universe is given by the following equation [8,9] :

$$m_u = \frac{c^3}{G \cdot H_0} \approx 1.73 \times 10^{53}\,\mathrm{kg} \tag{6}$$

In other works that we have already shown [2], we made the hypothesis that *N* was intimately linked to the fine structure constant $\alpha$.

$$N = \frac{m_u}{m_{ph}} = \frac{1}{\alpha^{57}} \approx 6.30 \times 10^{121} \tag{7}$$

This conjecture has allowed us to find the equations **(1)** and **(4)**. For now, we can not make a formal demonstration of equations **(1)**, **(4)** and **(7)** from known theories. However, the truth of these is indirectly demonstrated by the fact that we can calculate precisely [10], with these latter, the mass of the electron $m_e$ and getting exactly the same mass value of the electron $m_e$ than the CODATA 2010 [3]. Considering that the mass of the electron $m_e$ is described with more than eight significant digits and that we get the same [10], we consider that this situation can not statistically be a coincidence.

### 2.4. Relation between the Apparent Radius of Curvature of the Universe $R_u$ and the Classical Radius of the Electron $r_e$

The apparent radius of curvature of the universe (sometimes called Hubble radius [11], radius of the universe [12] or curvature radius of spacetime [13]) is normally given by the following equation:

$$R_u = \frac{c}{H_0} \approx 1.28 \times 10^{26}\,\text{m} \tag{8}$$

However, with the Hubble constant value $H_0$ of the equation **(14)**, we are able to accurately determine the value of the apparent radius of curvature of the universe $R_u$:

$$R_u = \frac{r_e}{\beta^{1/2} \cdot \alpha^{19}} = \frac{r_e \cdot N^{1/3}}{\beta^{1/2}} \approx 1.2831078806 \pm 0.0000000081 \times 10^{26}\,\text{m} \tag{9}$$

Several other methods are described in a document that we published previously [14].

# 3. DEVELOPEMENT
## 3.1. Wavelength of a rotating photon

We show here that a photon is a particle that has a radius equal to the Planck length $L_p$ and that its wavelength $\lambda$ is a relativistic interpretation of its circumference ($2\pi \cdot L_p$) in rotation.

$$L_p = \sqrt{\frac{h \cdot G}{2 \cdot \pi \cdot c^3}} \approx 1.6 \times 10^{-35}\,\mathrm{m} \tag{10}$$

With his theory of relativity [15,16], Einstein showed that a rest mass $m_0$ which is accelerated to a relativistic speed $v$ (that is to say close to the speed of light) sees its mass increasing to a value $m$ with respect to an observer at rest. The factor allowing, for an observer at rest, to interpret the mass that is in motion at speed $v$ is the Lorentz factor $\gamma$.

$$m = \frac{m_0}{\gamma} = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{11}$$

In an document that we have already presented in the past [17], we have shown that even light cannot really reach the speed limit $c$ (although it is very close). In fact, the constant $c$ is an unattainable speed limit, including for the light itself. The true speed of light, for photons, is slightly below this limit and is $c$-$\varepsilon_v$. The value of the quantum speed (that is to say, the smallest speed increment that is possible) being $\varepsilon_v \approx 2.34 \times 10^{-114}$ m/s.

We understand that $c$-$\varepsilon_v \approx c$. In many cases, this approximation is adequate and gives a result that we consider correct. However, when it comes to understanding what is really possible to achieve from some of Einstein's equations, this approximation is not appropriate. Indeed, it suggests that it is possible to set $v = c$, but it is not the case because we would get a square root that would tend toward zero, implying a mass $m$ tending to infinity. In fact, it is impossible to have a mass greater than that of the apparent mass of the universe. When we accelerate an object close to the speed limit $c$, unfailingly we draw energy in the universe around us. Since the apparent mass of the universe $m_u$ is finite, we agree, by logic, that it is impossible to accelerate any mass more than what is required to give it the apparent mass of the universe $m_u$.

Consider a photon. Assume that we can describe a photon as a spherical particle of radius equal to the Planck length $L_p$ that rotates on itself while moving with a rectilinear and uniform manner (when not subjected to gravitational field). Its rotation is perpendicular to its direction of movement. The tangential speed of rotation can be extremely slow (equal to 0) or extremely fast ($c$-$\varepsilon_v$).

The speed quantum $\varepsilon_v$ is defined by the following equation [17] :

$$\varepsilon_v = \frac{c}{2 \cdot N} \approx 2.34 \times 10^{-114} \text{ m/s} \tag{12}$$

Einstein showed that an observer at rest located in the center of a disk of radius $r$ could perceive an increase in the circumference of the disk when the its edge is rotating at the speed $v$ [15]. The circumference is then perceived as being higher than $2\pi \cdot r$ because of the Lorentz factor.

$$\text{Circumference of the disc} = \frac{2\pi \cdot r}{\sqrt{1 - \frac{v^2}{c^2}}} \tag{13}$$

### 3.2. Case of a Photon Spinning to a Speed $c$-$\varepsilon_v$

Let's suppose the case where a photon whose circumference is equal to $2\pi$ the time the Planck length $L_p$ turns on itself with a tangential speed equal to the speed of light in vacuum $c$ minus the speed quantum $\varepsilon_v$. Viewed by an observer at rest in the center of the photon, the photon will have a circumference (wavelength $\lambda$) that will be equal to the apparent circumference of the universe $2\pi \cdot R_u$. The $R_u$ value is the apparent radius of curvature of the universe.

$$\text{Circumference of the photon} = \lambda = \frac{2 \cdot \pi \cdot L_p}{\sqrt{1 - \frac{\left(c - \varepsilon_v\right)^2}{c^2}}} = 2 \cdot \pi \cdot R_u \tag{14}$$

Let's simplify the $2\pi$ terms, the $c^2$ terms by introducing the equation **(12)** into equation **(14)**. Then let's make a slight approximation assuming that the term $1/N^2 \approx 0$:

$$R_u = \frac{L_p}{\sqrt{1 - \left(1 - \frac{1}{N} + \frac{1}{4 \cdot N^2}\right)}} \approx \frac{L_p}{\sqrt{\frac{1}{N}}} \approx L_p \cdot N^{1/2} \tag{15}$$

That is the case, as we have already stated this result [14]:

$$N = \frac{R_u^2}{L_p^2} \quad \text{or} \quad R_u = \sqrt{N} \cdot L_p \tag{16}$$

This equation is also described in the book of Sidharth [18].

### 3.3. Case of a Photon Rotating at a Zero Speed

At the other extreme of the rotational speed range, let's suppose the case of a photon that has a circumference $2\pi \cdot L_p$. If the photon has a rotational speed $v$ equal to zero,

$$\text{Circumference of the photon} = \lambda = \lim_{v \to 0} \frac{2 \cdot \pi \cdot L_p}{\sqrt{1 - \frac{v^2}{c^2}}} = 2 \cdot \pi \cdot L_p \tag{17}$$

This shows the case of a photon having the smallest possible size, i.e. with a circumference equal to $2\pi \cdot L_p$.

### 3.4. Wavelength Variation of the Photons Over Time

Gradually, as the universe expands, it needs the presence of photons that have a wavelength equal to the new apparent circumference of the universe. Moreover, this phenomenon must be instantaneous because the luminous universe expands at the speed of light. This causes a dilemma. Either there is creation of new photons or existing photons change themselves in wavelength.

A perpetual creation of new photons flagrantly breaks the principle of conservation of energy, as there would be a continuous creation of matter. As this seems impossible according to the law of conservation of energy, we abandon this path. Furthermore, this phenomenon is not instantaneous. This is not the right way to follow.

We have a second possibility. Existing photons are forced to change in wavelength over time at the rate of expansion of the universe. This phenomenon is gradual and occurs everywhere instantly and on uniform manner. It therefore seems a good hypothesis to follow.

The photons in the periphery of the luminous universe have a wavelength $\lambda$ equal to the apparent circumference of the universe, that is to say $2\pi \cdot R_u$:

$$\lambda = 2\pi \cdot R_u = 2\pi \cdot \frac{c}{H_0} \tag{18}$$

Light accelerates over time [4]. On the edge of the luminous universe [4] and after a period $\Delta t$, the speed of light $v_L$ becomes:

$$v_L = c \cdot (1 + \Delta t \cdot H_0) \tag{19}$$

The apparent age of the universe $T_u$ is given by:

$$T_u = \frac{1}{H_0} \tag{20}$$

The product between $\Delta t$ and the Hubble constant $H_0$ represents a relationship between $\Delta t$ and the apparent age of the universe $T_u$.

Over a short period of time $\Delta t$, the acceleration of light over time can be seen as a line segment. To know the total displacement during this time, it is to take the average speed and multiply by the $\Delta t$. If $\lambda_1$ is the current wavelength of the photons and $\lambda_2$ is the wavelength of the photons after a $\Delta t$ period, we have:

$$\lambda_2 - \lambda_1 = 2\pi \cdot \left( \frac{c + c \cdot \left(1 + H_0 \cdot \Delta t\right)}{2} \right) \cdot \Delta t \tag{21}$$

Rearranging this equation, we get:

$$\lambda_2 - \lambda_1 \approx 2\pi \cdot c \cdot \Delta t + 2\pi \cdot c \cdot H_0 \cdot \Delta t^2 \tag{22}$$

As the second term of this sum is very small compared to the first, we can approximate the result as following:

$$\lambda_2 - \lambda_1 \approx 2\pi \cdot c \cdot \Delta t \tag{23}$$

The annual variation (1 year = 31557600 s) of the wavelength $\Delta\lambda$ becomes:

$$\Delta\lambda = \frac{\lambda_2 - \lambda_1}{1\,\text{year}} \approx \frac{2\pi \cdot c \cdot 31557600\text{s}}{1\,\text{year}} \approx 5.9 \times 10^{16}\,\text{m/year} \tag{24}$$

To know the wavelength variation $\Delta\lambda'$ from any wavelength $\lambda'$, simply divide it by $\lambda$ to obtain a proportion and then apply this fraction by multiplying it to the variation $\Delta\lambda$:

$$\Delta\lambda' \approx \frac{\lambda'}{\lambda} \cdot \Delta\lambda \tag{25}$$

With equations **(18)** and **(24)** we find that the apparent radius of the luminous universe $R_u$ increases annually:

$$\Delta R_u \cdot 1\,\text{year} = c \cdot 31557600\text{s} \approx 9.5 \times 10^{15}\,\text{m} \tag{26}$$

Knowing that the actual radius of a photon is the Planck length $L_p$ and its wavelength depends upon its rotational speed, we conclude that the rotational speed of a photon increases over time to ensure that its wavelength increases.

We mention that the light escaping from a star will see its full spectrum slowly shifting to red over time, simply by the fact that the universe is expanding. Indeed, as the universe expands, the entire universe is moving away from its center of mass. The refractive index of the vacuum decreases and allows an increase in the speed of light in vacuum. This phenomenon has also been detected using the Doppler effect. This is what has enabled Hubble to make the assumption that the universe was expanding.

According to the principle of conservation of energy, the energy of a photon $E_{ph}$ must remain constant over time. The product between the mass associated with photons $m_{ph}$ by the square of the speed of light must remain constant:

$$E_{ph} = m_{ph} \cdot c^2 = \text{constant} \tag{27}$$

As the speed of light increases over time, the mass $m_{ph}$ is forced to decrease.

Let's remember that the number $N$ is defined as the mass of the universe $m_u$ divided by the mass associated to a photon $m_{ph}$ [7].

$$N = \frac{m_u}{m_{ph}} \tag{28}$$

As the mass of the universe is, at base, itself composed of photons, it follows that the apparent mass of the universe $m_u$ also decreases over time to keep at the same rhythm than $m_{ph}$. Changes proportionally being identical to the numerator and to the denominator of equation **(28)**, it follows that the value of $N$ is constant over time. As the value of $N$ is related to the fine structure constant, the fine structure constant $\alpha$ is constant over time.

The fine structure constant $\alpha$ is one of the few constants have no units. In fact, this is because it represents a ratio. It can be defined as the ratio between the classical radius of the electron $r_e$ and the Compton radius $r_c$ of the electron.

$$\alpha = \frac{r_e}{r_c} \tag{29}$$

Like the constant $N$, potential variations over time in the numerator are cancelled by the same variations in the denominator.

### 3.5. Variation of Particle Size over Time

Due to the fact that the wavelengths of the electromagnetic spectrum shift to larger wavelengths, a question arises. Are we able to detect the wavelength variation of the electromagnetic spectrum? The answer may depend on the procedure used.

If we measure the wavelengths using hyperfine rays of reference, the answer is no, because these lines are themselves affected by the change in refractive index over time.

Is a mechanical meter of reference can actually serve as a reference? Maybe not because the shift over time could possibly affect the size of atoms over time. Indeed, as we mentioned in the equation **(9)**, the apparent radius of curvature of the universe can be defined in terms of the classical radius of the electron as follows [14]:

$$R_u = \frac{r_e}{\beta^{1/2} \cdot \alpha^{19}} \tag{30}$$

As $\beta$ and $\alpha$ are truly constant over time and that the apparent radius of curvature of the universe $R_u$ increases over time, it becomes clear that the classical radius of the electron $r_e$ is forced to grow over time. Indirectly, this implies that the neutron is also obliged to see its measurements increasing over time because according to the standard model, the neutron decays as follows:

$$\text{neutron} \Leftrightarrow \text{proton} + \text{electron} + \text{antineutrino} \tag{31}$$

The neutron is therefore itself built with an electron. We could bet that the proton and all the other particles in the universe also are expanding over time. This is also the basis for the Big Bang theory. In other words, the universe is expanding, since all its constituents, including matter, are expanding.

So, a mechanical reference meter can not really serve as a standard for such precision measurements since it is itself affected by the expansion of the universe. As Dirac has rightly mentioned, several "constants" of physical might in fact vary over time and distort our understanding of the dimensions of the universe.

## 4. CONCLUSION

In this document, we show that a photon is a particle of radius equal to the Planck length $L_p$ and that its wavelength $\lambda$ can be considered as being a relativistic interpretation of its circumference ($2\pi \cdot L_p$) in rotation. The wavelength $\lambda$ that is associated to a photon depends only on its rotation speed.

The universe is expanding and all the photons that make it up see their wavelength increasing over time. It is the same for the particle size that make up matter and all our standards used for determining the distance units. However, as the standards themselves are affected by the same phenomenon, no one can "measure" the phenomenon. For now, unless we find a new way to measure the distances that is not influenced by the expansion of the universe, it may be difficult to make measurements of such precision adequately. By identifying well the physics "constants" that are really constant over time, it may be possible to find a independent measurement method that is insensitive to the fact that the universe is expanding. We have to be well aware of the variation of the various parameters over the time.

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