On the Speed of the Light in a Gravitational Field

January 30, 2018.

José Francisco García Juliá

jfgj1@hotmail.es

When a body emits a light, its speed decreases due to the gravity.

Key words: speed of the light, gravity.

For a particle of mass m and speed v, in a gravitational field with potential φ, we have that [1]

$$T = (1/2)mv^2 \tag{1}$$

$$V = m\varphi \tag{2}$$

T and V being the kinetic and potential energies of the particle, respectively.

Therefore, for a photon (assuming an "effective mass" [2] $m = hf/c^2$, where h is the constant of Planck, f the frequency and c the velocity of the light in the vacuum)

$$T = hf \tag{3}$$

$$V = (hf/c^2)\varphi \tag{4}$$

As the gravitational field is conservative, then

$$T + V = hf + (hf/c^2)\varphi = const. \tag{5}$$

$$hf_o + (hf_o/c^2)\varphi_o = hf_e + (hf_e/c^2)\varphi_e \tag{6}$$

$$f_o\left(1 + \frac{\varphi_o}{c^2}\right) = f_e\left(1 + \frac{\varphi_e}{c^2}\right) \tag{7}$$

where f_e and f_o are the light frequencies emitted and observed of the photon, respectively, and φ_e and φ_o the potentials in the points of emission and observation, respectively.

On the other side, from (5), and adapting the escape velocity concept [3] for a photon (with $m = hf_e/c^2$ and $c = \lambda_e f_e$, where λ_e is the light wavelength emitted of the photon), we have that

$$\frac{hv_{eph}}{\lambda_e} + \frac{hc}{\lambda_e c^2}\varphi_e = 0 \tag{8}$$

$$v_{eph} = -\frac{\varphi_e}{c} = \frac{GM}{Rc} \tag{9}$$

G being the gravitational constant of Newton and v_{eph} the escape velocity of a photon emitted by a body of mass M and radius R (and $\varphi_e = -\frac{GM}{R}$).

Now, from (7) and (9)

$$f_o \left(1 + \frac{\varphi_o}{c^2}\right) = f_e \left(1 + \frac{\varphi_e}{c^2}\right) = f_e \left(1 - \frac{v_{eph}}{c}\right) = \frac{c}{\lambda_e}\left(1 - \frac{v_{eph}}{c}\right) = \frac{c - v_{eph}}{\lambda_e} \quad (10)$$

$$f_o = \frac{c - v_{eph}}{\left(1 + \frac{\varphi_o}{c^2}\right)\lambda_e} = \frac{c_o}{\lambda_o} \quad (11)$$

where $\lambda_o = \left(1 + \frac{\varphi_o}{c^2}\right)\lambda_e$ is the light wavelength observed of the photon. And the speed of the observed photon is $c_o = \lambda_o f_o = c - v_{eph}$.

This decrease of the speed of the light produce a gravitational refractive index n

$$\frac{c}{n} = c - v_{eph} = c - \frac{GM}{Rc} \quad (12)$$

$$n = \frac{1}{1 - \frac{GM}{Rc^2}} \quad (13)$$

This gravitational refractive index implies that the force of the gravity is an electromagnetic force [4], and also affects to the existence of the (classical or Michell) black holes [5].

In summary, when a body emits a light, its speed decreases due to the gravity.

[1] José Francisco García Juliá, Gravitational Redshift, viXra: 0903.0001 [Relativity and Cosmology]
http://vixra.org/abs/0903.0001

[2] R. F. Evans and J. Dunning-Davies, The Gravitational Red-Shift, arXiv: gr-qc/0403082v1 (2004).
https://arxiv.org/abs/gr-qc/0403082

[3] John W. Norbury, From Newton's Laws to the Wheeler-DeWitt Equation, arXiv: physics/9806004v2 (1998).
https://arxiv.org/abs/physics/9806004

[4] José Francisco García Juliá, On the Gravitational Force, viXra: 1602.0093 [Classical Physics]
http://vixra.org/abs/1602.0093

[5] José Francisco García Juliá, On the Existence of the Black Holes, viXra: 1602.0092 [Classical Physics]
http://vixra.org/abs/1602.0092