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Encuentros Multidisciplinares

ON THE GRAVITATIONAL FIELD CREATED BY ELECTROMAGNETIC RADIATIONS

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ABSTRACT

By combining the expression which connects mass and energy by Einstein with the relation between the light velocity, permeability and the permittivity of the vacuum deduced by Maxwell, new equations have been deduced, which allow to evaluate the force of the interaction between mass and radiation as well as the gravitational interaction between radiations. According to the equation deduced it can be said that gravity and electromagnetism are manifestations of a unique field of forces.

1. AIMS AND PROCEDURES OF THE STUDY

In year 1924 the French physicist Louis de Broglie presented his doctor work[1], in which he expressed the idea that every material body is accompanied by a wave whose wavelength is inversely proportional to the mass of the body concerned. In order to come to this conclusion, De Broglie took the expression of the energy as a function of the frequency proposed by Planck[2] (E = hν), who introduced the so called quantum of action, h. He equalized this expression with the equation relating mass and energy deduced by Einstein[3].

In this study, it has been started from an equalizing of the value of the square of the light velocity, which can be derived from the Einstein equation, with the same value deduced using the Maxwell equation for the light velocity[4]: $c = (\mu_0\varepsilon_0)^{-1/2}$. In this way it is possible to deduce a relation between mass and frequency, as it follows:

$$c^2 = \frac{1}{\mu_0\varepsilon_0} = \frac{E}{m} \qquad (Equation\ 1)$$

Where c stands for the light velocity in the vacuum, E for the energy, m for the mass and μ_0 and ε_0 for the vacuum permeability and the vacuum permittivity, respectively. The value of the energy which can be derived from Equation 1 can be equalized with the same value proposed by Planck. Thus:

$$E = \frac{m}{\mu_0\varepsilon_0} = h\nu = \frac{hc}{\lambda} \qquad (Equation\ 2)$$

From this expression it is easy to derive following expressions for the mass attributive to a radiation of a frequency equal to ν:

$$m = \mu_0\varepsilon_0 h\nu = (constant)\ \nu \qquad (Equation\ 3)$$

Where:

$$(constant) = \mu_0 \varepsilon_0 h = \frac{h}{c^2} = 7.3624 \times 10^{-54}\ kg \times s \qquad (Equation\ 4)$$

The dimensions of the proportionality constant between mass and frequency of radiation are MT, a mass multiplied by time.

Equation 3 shows that mass and frequency of an electromagnetic radiation are proportional to each other, where the proportionality constant, given by Equation 4, is the product of three universal constants: the vacuum permittivity, the vacuum permeability and the Planck constant.

Taking into account the relation between wavelength and frequency of a radiation: $\nu = c/\lambda$, Equation 3 can be also written as follows

$$m = \mu_0 \varepsilon_0 \frac{hc}{\lambda} \qquad (Equation\ 5)$$

According to this equation there exits an inverse proportionality between mass and wavelength. It follows that the product of the mass of a body by his wavelength is a constant, which can be expressed as the product of four universal constants:

$$m\lambda = \mu_0 \varepsilon_0 hc = (constant) \qquad (Equation\ 6)$$

This is the equation of a hyperbola.

Where:

$$\mu_0 \varepsilon_0 hc = \frac{h}{c} = 2{,}21026 \times 10^{-42}\ Kg \times m =$$
$$= 2{,}21026 \times 10^{-30}\ nanog \times m =$$
$$= 2{,}21026 \times 10^{-21}\ nanog \times nanom$$

Equation 6 can be considered an expression of the duality wave-corpuscle, which indicates that mass and wavelength are closely related to each other.

Implication of Equation 6 to the gravitational interaction between radiations and between radiations and mass

Equations 3 or 5 can be used for representing the masses of two bodies in Newton´s gravitation equation:

$$F = G\frac{m\,m'}{r^2} \qquad (Equation\ 7)$$

Where F represents the gravitational attraction force between two bodies of masses m and m´, G is the gravitation constant proposed by Newton and r the separation distance between both.
With:

$$m = \mu_0 \varepsilon_0 h\nu \qquad (Equation\ 8)$$

And:

$$m' = \mu_0 \varepsilon_0 h\nu' \qquad (Equation\ 9)$$

Substituting these values in Equation 6, it results:

$$F = G(\mu_0 \varepsilon_0 h)^2 \frac{\nu\,\nu'}{r^2} = A\frac{\nu\,\nu'}{r^2} \qquad (Equation\ 10)$$

Where the constant A is the result of a combination between universal constants:

$$A = [G(\mu_0 \varepsilon_0 h)^2] = \left(\frac{h^2}{c^4} G\right) \qquad (Equation\ 11)$$

According to Equation 10, two different radiations of frequencies ν and ν´ would attract themselves with a force proportional to both frequencies and inversely proportional to the square of the distance between them. The proportionality constant is given by Equation 11 and its physical dimensions can be deduced to get following expression:

$$|A| = \left|\frac{h^2}{c^4}\right| |G| = \left|\frac{(M\, L^2\, T^{-1})^2}{L^4\, T^{-4}}\right| |M^{-1} L^3\, T^{-2}| = ML^3 \qquad (Equation\ 12)$$

The proportionality constant in Equation 9 has dimensions of a volume by a mass, representing tridimensional space and mass. The value of A, calculated by substitution of the values of h, c and G in Equation 12, is: $A = 3.6271\times10^{-99}$ kg m^3.

A similar equation can be written as a function of the wavelengths of the radiations, λ and λ´, taking into account that: ν = (c/λ) and ν´ = (c/λ´). Substituting these values in Equation 9, it results:

$$F = G(\mu_0 \varepsilon_0 h)^2 \frac{c^2}{\lambda\, \lambda' r^2} = (Ac^2) \frac{1}{\lambda\, \lambda' r^2} = B\ \frac{1}{\lambda\, \lambda' r^2} \qquad (Equation\ 13)$$

Where the proportionality factor B is given by:

$$B = \underbrace{G(\mu_0 \varepsilon_0 h)^2}_{A} c^2 = Ac^2 = \left(\frac{h}{c}\right)^2 G \qquad (Equation\ 14)$$

And the physical dimensions of B are:

$$|B| = |A||c^2| = |ML^3||L^2\, T^{-2}| = ML^5 T^{-2} \qquad (Equation\ 15)$$

The proportionality constant, B, has a value that can be calculated by substitution of the values of A and c in Equation 12 is:

$$B = (3.264\times10^{-82}\ \mathrm{N\ m^4} = 3.264\times10^{-82}\ \mathrm{kg\ m^5\ s^{-2}})$$

In a similar way, it can be deduced that there exists a gravitational attractive interaction between a body of mass M and a radiation of frequency ν, given by following equation:

$$F = G(\mu_0 \varepsilon_0 h) \frac{M\, \nu}{r^2} = C \frac{M\, \nu}{r^2} \qquad (Equation\ 16)$$

Where the proportionality constant C is given by:

$$C = \frac{A}{\mu_0 \varepsilon_0 h} = A \frac{c^2}{h} = \left(\frac{h^2}{c^4} G\right) \frac{c^2}{h} = \frac{h}{c^2}\ G = \frac{B}{h} \qquad (Equation\ 17)$$

The value of C, calculated by substitution of the values of G, h and c in Equation 12 is:

$$C = 4.92\times10^{-61}\ \mathrm{N\ kg^{-1}\ m^2\ s}$$

The proportionality constant, D, for the interaction between the Sun (M_{Sun} = 1.989 ×10^{30} kg) and a radiation of frequency ν passing at a distance r from the star would be given by multiplication of C by M_{Sun}, Thus:

$$(C \times M_{Sun}) = D = 9.786 \times 10^{-31}\ N\ m^2\ s$$

Table 1 gives account of the different proportionality constants, their SI units and their physical dimensions.

Table 1

G = gravitational constant; μ_0 = vacuum permittivity; ε_0 = vacuum permeability

Interaction	*Equation*	*Proportionality constant*	*SI Units of the constant*	*Physical dimensions*
Gravitational interaction between radiations (frequencies)	$F = A\frac{\nu\nu'}{r^2}$	$A = G(\mu_0\varepsilon_0)h^2 = \left(\frac{h^2}{c^4}\right)G =$ $= 3.6271 \times 10^{-94}$ kgm^3 $= 3.264\ \times 10^{-82}$ Nm^2s^2	$kgm^3;\ \ Nm^2s^2$	ML^3
Gravitational interaction between radiations (wavelengths)	$F = B\frac{1}{\lambda\lambda' r^2}$	$B = \left(\frac{h}{c}\right)^2 G == 3.6271 \times 10^{-94}$ $= 3.264\ \times 10^{-82}$ $kgm^5s^{-2} =$ $= 3.264\ \times 10^{-82}$ Nm^4	kgm^5s^{-2} Nm^4	ML^5T^{-2}
Gravitational interaction between a body of mass M and a radiation of frequency ν	$F = C\frac{M\nu}{r^2}$	$C = [G(\mu_0\varepsilon_0)h] =$ $= \frac{h}{c^2}G =$ $4.92\ \times 10^{-61}$ m^3s^{-1}	m^3s^{-1}	L^3T^{-1}

According to Equation 16, the gravitational interaction between a body of mass M and a radiation of frequency ν is directly proportional to the mass of the body, M, and to the radiation frequency, ν, and inversely proportional to the square of the distance between body and radiation. On the other hand, when a light beam characterized by an electromagnetic spectrum of radiations of different frequencies, interacts with a body of mass M, each of the frequencies would be attracted (and, therefore, conveniently deviated) by the mass M with a force proportional to M and ν. Thus, the presence of a body of mass M would give rise to attractions of different intensities for different frequencies of radiation, acting like a prism with respect to a beam of polychromatic light. The higher the frequency of the radiation, the most intense would be the interaction between M and the corresponding frequency and more deviated would result the corresponding radiation.

It can be concluded, that the mass M distorts the space around it in such a way that it changes the electromagnetic properties of the space through which the radiation beam travels and that the intensity of the change is directly proportional to the radiation frequency. Since frequency and mass are proportional to each other, it can be also said that the radiation gives rise to a distortion of the space throughout it travels, changing the electromagnetic properties of it, so much intensively as higher is the frequency of the radiation considered.

In a similar way, expressions for the interaction between mass and radiation can be deduced in which the relativistic effects are taken into account. In such a case the relativistic expression for the mass of a body moving at a velocity v can be expressed as follows:

$$M = \frac{M_0}{\sqrt{1 - \frac{v^2}{c^2}}} \qquad (Equation\ 18)$$

Substituting this expression for M in Equation 16, following equation can be deduced:

$$F = G(\mu_0 \varepsilon_0 h) \frac{M\,\nu}{r^2} = C \frac{M\,\nu}{r^2} = C\ \frac{M_0\,\nu}{r^2 \left(1 - \frac{v^2}{c^2}\right)^{1/2}} \qquad (Equation\ 19)$$

According to this expression, the gravitational interaction between a body of a rest mass equal to M_0 and a radiation of frequency ν would increase with the velocity of displacement of the mass M_0 and would tend to infinity for velocities close to the light velocity. For velocities of displacement approaching the light velocity, the denominator in Equation 19 tends to zero and, therefore, the force of interaction would tend to infinite.

2. RESULTS AND CONCLUSIONS

By combining the expression which connects mass and energy by Einstein with the relation between the light velocity, permeability and the permittivity of the vacuum deduced by Maxwell, a new equation has been deduced, which allows to evaluate the force of the interaction between mass and radiation as well as the gravitational interaction between radiations. According to the equation deduced it can be said that gravity and electromagnetism are manifestations of a unique field of forces.

Attractive interactions between mass and radiation and between radiations can also be predicted.

The main implication of the ideas above expressed and, particularly, of Equation 10, is that the gravitational field created by the radiations emitted during the 13700 millions of years since the big bang (or, since the creation of the universe) could afford an explanation for the gravitational effect attributed to the so called dark matter and dark energy. The energy in form of radiations emitted along the years elapsed since the creation of the universe should be conserved, according to the principle of conservation of the energy, and these radiations would exert a gravitational effect on masses and radiations, which could also offer an explanation for the effects attributed to dark matter and dark energy.

In other words, the radiation existing as a rest of all radiations emitted through all the time elapsed since the creation of the universe could be responsible for the effects attributed to dark matter and dark energy. The whole radiation emitted during 13.700 million years is preserved in the form of a radiation of maximum wavelength corresponding to a maximum of entropy[5].Thus, due to the duality between mass and energy, the gravitational effect exerted by these radiations could explain the effect that today is attributed to the existence of a supposed black matter and black energy.

Some consequences of the gravitational interaction among radiations predicted by Equation 10

Another implication of Equation 6, which expresses that the product of mass by wavelength is a constant, was already predicted by the own Einstein in one of his works[6]. According to Einstein, matter could be considered as congealed energy and light quanta (this is the name employed by Einstein for the now called photons) consist of particles which had changed their masses in the process of reaching the speed of light. In their translation through the space as a light beam, photons would dissipate their energy and this loss of energy cannot be explained by a change in their speed of translation, since the speed of light is a universal constant. Therefore, the loss in energy should be attributed to a loss of mass, which, according to Equation 6, would result in an increase of the wavelength, i.e., in a shift towards the red. This shift was already predicted in the article above cited, in which it was called “gravitational shift to the red”.

According to the ideas expressed in the last paragraph, the energy dissipation experimented by a light beam can be explained also as a consequence of gravitational interaction between the radiations composing a light beam and the so called cosmic background radiation which uniformly occupies the whole space in the universe. In order to overcome the gravitational interaction with the background radiation, any light beam travelling through the space should lose part of its energy. Thus, it could be said that the background radiation acts like a brake for light travelling through it.

Due to the fact that the light velocity is a universal constant, the energy necessary for overcoming this gravitational interaction which gives rise to the braking of the light beam, could arise from a partial conversion in energy of the mass attributed to the photons.

Gravitational interaction among radiations is predicted by Equation 10 and would act like a resistance to the displacement of the light beam. The very reduced value calculated for constant A in Equation 10 ($A = 3.6271\times10^{-99}$ kg m^3) indicates that the value of the gravitational interaction between radiations composing the light beam and the background radiation should also be extremely small and it could only give rise to a measurable shift to the red, after a long translation of the light through space.

On the other hand, the more far away were the cosmic bodies emitting light beams, the more extended would be the space to be covered and the larger would be the resulting red shift experimented by the radiations composing the light beam. The gravitational interaction between the mass equivalent to the degraded radiation (background radiation) and the light beam could explain the red shifts detected. In addition to these effects, the interaction between the background radiation and the different photons forming part of a radiation beam should be proportional to the frequency. Therefore, the more energetic would be the photons the stronger would be their interaction with the background radiation and, consequently, the faster their mass lost and the faster their conversion in photons of larger wavelength.

Thus, according to these ideas, it could be said that a beam of light displaces itself through the space interacting with the background radiation and losing a part of its energy in the process of translation. The loss of energy corresponds itself with a loss of mass, which, according to Equation 6 should give rise to an increase of the wavelength of the radiations composing the beam, which implies a shift to the red. According to this interpretation, the shift to the red attributed to Doppler´s effect, could also be attributed to the energy dissipated by a light beam in its displacement through the space.

This shift would be more pronounced the longer the displacement, i. e, the more distant would be the body emitting the light beam. Since the background radiation is uniformly distributed through the space, a displacement two times longer should give rise to a double shift to the red. It can be said that the gravitational redshift predicted by Einstein is coincident with the redshift attributed to a Doppler effect. Therefore, the loss of mass exprimented by the photons forming part of the light beam would be larger, the more distant would be the light source, which would result in a longer shift to the red of the light.

The red shift which has been attributed to the Doppler effect, could also be due to a loss in energy (and, therefore, in mass, which would result in an increase in the wavelength of the radiation resulting from the loss in mass) which would experiment a light beam as a consequence of the energy used up in the process of displacement. The longer the space travelled by the light, the larger would be the red shift experimented by the light. This idea is in contradiction with the consequence resulting from attributing the red shift to a Doppler effect: that the more distant are the light emitting bodies, the longer is the red shift, which, according to the interpretation based in the cited effect, would correspond to increasing receding velocities of the light emitting bodies.

According to Einstein´s general theory of relativity, light, like matter, feels the influence of gravitation. As a consequence of this effect, light escaping from a gravitational field loses part of its energy due to the braking effect exerted by this field. Since the light velocity is a universal constant, the loss in energy suffered by the light cannot be attributed to a decrease in its velocity (since this is an universal constant), but to a conversion of part of the mass of the photons forming part of the radiation, which, according to Equation 6 should result in an increase of the wavelength. This is the gravitational redshift predicted by Einstein.

It can be said that the prediction made by Einstein about the existence of a gravitational red shift can also afford an explanation for the red shift observed in radiations proceeding from light emitting cosmic bodies. On the other hand, the existence of a background radiation with the corresponding mass and the corresponding gravitational effect could also afford an explanation for the so called cosmological constant introduced by Einstein (and eventually retired) in order to support the model of stable Universe initially defended by him and eventually abandoned after visiting the Mount Wilson astronomic observatory and being convinced by Hubble on the Doppler effect influence on the light.

The gravitational effect on the red shift can be understood as a measure of the age of the light. The higher the observed red shift, the longer the way travelled by the beam, the higher the loss of mass of the photons and, consequently, the higher the red shift experimented by the radiations and the older the instant of its emission.

That the background radiation could also play the same role as the attributed to the so called dark matter and dark energy was already mentioned by Weinberg[7], according to whom: the existence of a background radiation covering every corner of the Universe contributes to increase the energetic density of the vacuum, which would give rise to the same result on the general relativity theory as the cosmological constant did.

Other authors[8] maintain that the explanation of the Universe requires the use of a cosmological term different to the term added by Einstein in his general relativity theory (and eventually retired after his conversations with Hubble during his visit to Mount Wilson). These authors, using a mechanic-quantal approach to the problem, in which it is necessary to stablish the premise that the vacuum space in the Universe contains energy, deduced a cosmological term different to the added by Einstein.

The ideas derived from the gravitational red shift predicted by Einstein would also have as a consequence a debate on the validity of the model of Universe based on the so called big-bang.

3. REFERENCES

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