Photon – the minimum dose of electromagnetic radiation

Tuomo Suntola

Suntola Consulting Ltd., Tampere University of Technology, Finland

A radio engineer can hardly think about smaller amount of electromagnetic radiation than given by a single oscillation cycle of a unit charge in a dipole. When solved from Maxwell's equations for a dipole of one wavelength, the energy of the emitted radiation cycle obtains the form $E_\lambda = 2/3\ hf$, where the Planck constant h can be expressed in terms of the unit charge, e, the vacuum permeability, μ_0, the velocity of light, c, and a numerical factor as $h = 1.1049{\cdot}2\pi^3 e^2 \mu_0 c = 6.62607{\cdot}10^{-34}$ [kgm^2/s]. A point emitter like an atom can be regarded as a dipole in the fourth dimension. The length of such dipole is measured in the direction of the line element cdt, which in one oscillation cycle means the length of one wavelength. For a dipole in the fourth dimension, three space directions are in the normal plane which eliminates the factor 2/3 from the energy expression thus leading to Planck's equation $E_\lambda = hf$ for the radiation emitted by a single electron transition in an atom. The expression of the Planck constant obtained from Maxwell's equations leads to a purely numerical expression of the fine structure constant $\alpha = 1/(1.1049{\cdot}4\pi^3) \approx 1/137$ and shows that the Planck constant is directly proportional to the velocity of light. When applied to Balmer's formula, the linkage of the Planck constant to the velocity of light shows, that the frequency of an atomic oscillator is directly proportional to the velocity of light. This implies that the velocity of light is *observed* as constant in local measurements. Such an interpretation makes it possible to convert relativistic spacetime with variable time coordinates into space with variable clock frequencies in universal time, and thus include relativistic phenomena in the framework of quantum mechanics.

Keywords: Photon, Maxwell's equations, quantum of radiation, Planck's equation, absolute time

INTRODUCTION

We are used to thinking that the emission of electromagnetic radiation described by Planck's equation is different from the emission of radiation from a dipole according to Maxwell's equations. Based on observations on back body radiation, the emission of electromagnetic radiation from a heated body, Max Planck in about 1900 concluded that the dose of electromagnetic radiation, a quantum, that can be emitted grows in a direct proportion to its frequency, expressed as $E = hf$. In this presentation, we will find out that emission of electromagnetic radiation from an electric dipole has basically the same property — once we solve for the energy of one cycle of radiation.

In explaining Philipp von Lenard's experiments on the photoelectric effect, Albert Einstein in 1905 applied an opposite aspect of Planck's postulate. To have electrons emitted from a solid surface, the energy quantum of incoming radiation shall exceed the work function needed in releasing an electron. Einstein's explanation was verified by the successful determination of Planck's constant from the photoelectric effect.

The works of Planck and Einstein inspired Niels Bohr to combine particle and wave properties of an electron in his model for hydrogen atom. In Bohr's model, discrete stationary energy states are characterized by standing waves with momentum equal to the momentum of electrons orbiting the nucleus in a classical Coulomb field.

Planck's postulate and the explanation of the photoelectric effect using the concept of the quantum led towards a dualistic view of electromagnetic radiation as a wavelike form of energy described in terms of Maxwell's equations and also as a flow of particles like quanta. Such dualistic view was strengthened through the analysis of Compton scattering of radiation based on the works of Arthur H. Compton and Peter Debye in the early 1920's. An important aspect was the momentum of a quantum which, as a zero rest mass particle in the framework of special relativity, could be identified as equal to the momentum of electromagnetic radiation according to Maxwell's equations, i.e. $E = c|\mathbf{p}|$. A complementary view of the dualism between particles and waves was established through the work of Louis de Broglie who generalized the concept of the wavelength equivalence, the de Broglie wavelength $\lambda_{dB} = h/|\mathbf{p}|$, of mass particles with momentum $\mathbf{p}$ in space, an idea implicitly included in the Bohr hydrogen atom about ten years earlier. Schrödinger's equation completed the framework of quantum mechanics in the late 1920's.

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Key conclusions leading to quantum mechanics have been drawn from phenomena related to atoms and small particles. Emission of electromagnetic radiation from atoms as small point sources could not be quantitatively explained in the framework of Maxwell's equations. When an atomic source is described as an electric dipole emitting electromagnetic radiation, the displacement of the charge resulting in electric dipole momentum is considered as being of the order of atomic size, about 10^{-10} m, which is orders of magnitudes smaller than the wavelengths of radiation emitted. The situation, however, is radically changed if we consider a point source a dipole in the fourth dimension, in the direction of line element *cdt*, which in one oscillation cycle means the displacement of one wavelength — regardless of the emission frequency from the source.

When solved from Maxwell's equations, the energy of one cycle of electromagnetic radiation emitted from a dipole in the fourth dimension due to a single transition of a unit charge obtains the form of Planck's equation $E = hf$. Such a result gives the quantum a clear meaning as the energy of one cycle of electromagnetic radiation generated by a single electron transition in a point source.

Interpretation of a point source as a dipole in the fourth dimension suggests a fourth dimension of metric nature. Displacement of a point source by one wavelength in a cycle requires motion of space at velocity c in the metric forth dimension. Such an interpretation is consistent with spherically closed space expanding in a zero energy balance of motion and gravitation in the direction of the 4-radius. A consequence of the conservation of the zero energy balance in interactions in space is that all velocities in space become related to the velocity of space in the fourth dimension, and all gravitational states in space become related to the gravitational state of spherically closed space.

1. OSCILLATING ELECTROMAGNETIC DIPOLE

1.1. Electric dipole in 3-dimensional space; the standard solution

Moving electric charges result in electromagnetic radiation through the buildup of changing electric and magnetic fields as described by Maxwell's equations. The electric and magnetic fields produced by an oscillating electric dipole at distance r ($r/z_0 > 2z_0/\lambda$) can be expressed as

$$\vec{\mathcal{E}} = \frac{\Pi_0 \omega^2 \sin\theta}{4\pi\varepsilon_0 r c^2} \sin(kr - \omega t)\, \hat{\mathbf{r}}_\theta \tag{1}$$

and

$$\vec{\mathcal{B}} = \frac{1}{c}\mathcal{E}\, \hat{\mathbf{r}}_\varphi = \frac{\Pi_0 \omega^2 \sin\theta}{4\pi\varepsilon_0 r c^3} \sin(kr - \omega t)\, \hat{\mathbf{r}}_\varphi \tag{2}$$

where θ is the angle between the dipole and the distance vectors and

$$\Pi_0 = Nez_0 \tag{3}$$

is the peak value of the dipole momentum, where N is the number of unit charges, e, oscillating in a dipole of effective length z_0. Both field vectors, $\vec{\mathcal{E}}$ and $\vec{\mathcal{B}}$, are perpendicular to the distance vector $\mathbf{r}$. The Poynting vector, showing the direction of the energy flow, has the direction of $\hat{\mathbf{r}}$ (see Figure 1).

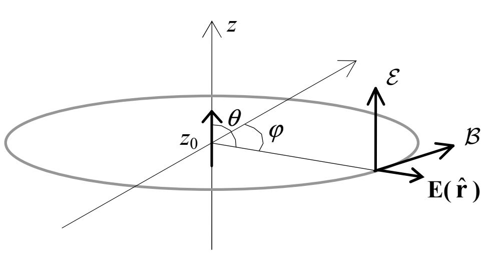

Figure 1. An electric dipole in the direction of the z-axis results in maximum radiation density in the normal plane of the dipole, $\theta = \pi/2$.

The energy density of radiation can be expressed as

$$\mathsf{E} = \varepsilon_0 \mathcal{E}^2 = \frac{\Pi_0^2 \mu_0 \omega^4 \sin^2\theta}{16\pi^2 r^2 c^2} \sin^2\left(kr - \omega t\right) \tag{4}$$

where ε_0 has been expressed in terms of μ_0 as $\varepsilon_0 = 1/\mu_0 c^2$. The average energy density of radiation is

$$\mathsf{E}_{\text{ave}} = \frac{E_0}{2\pi}\int_0^{2\pi} \sin^2\left(kr - \omega t\right) d\left(\omega t\right) = \frac{1}{2}E_0 = \frac{\Pi_0^2 \mu_0 \omega^4}{32\pi^2 r^2 c^2}\sin^2\theta \tag{5}$$

The average power radiating through a sphere with radius r around the radiating dipole is

$$P = \left\langle \frac{dE}{dt} \right\rangle = \int_s c\,\mathsf{E}_{\text{ave}} dS = \frac{\Pi_0^2 \mu_0 \omega^4}{32\pi^2 r^2 c}\int_s \sin^2\theta\, dS = \frac{\Pi_0^2 \mu_0 \omega^4}{12\pi c} \tag{6}$$

By substituting equation (3) for Π_0 in equation (6), the energy flow in one cycle can be expressed as

$$E_\lambda = \frac{P}{f} = \frac{N^2 e^2 z_0^2 \mu_0 16\pi^4 f^4}{12\pi c f} = N^2\left(\frac{z_0}{\lambda}\right)^2 \frac{2}{3}\left(2\pi^3 e^2 \mu_0 c\right) f \tag{7}$$

In equation (7) the angular frequency ω has been converted to frequency $f = \omega/2\pi$, and the length of the dipole z_0 has been related to the wavelength $\lambda = c/f$.

Equation (7) means that the energy emitted by an electric dipole in a cycle is directly proportional to the frequency emitted. The factor 2/3 in equation (7) is the ratio of the average power emitted to all space directions to the maximum power emitted in the normal plane of the dipole. The factor $2\pi^3 e^2 \mu_0 c$, has the dimensions of momentum–length, like Planck's constant h, and has the numerical value of $2\pi^3 e^2 \mu_0 c_0$ is $5.997 \cdot 10^{-34} = h/1.1049$ [kgm^2/s].

1.2. Point source as an electric dipole in the fourth dimension

In one cycle of emission, a point source at rest in space moves a distance

$$z_4 = cdt = \frac{c}{f} = \lambda \tag{8}$$

in the fourth dimension characterized by line element i cdt in an imaginary direction perpendicular to space directions. Accordingly, emission to any space direction from a dipole in the fourth dimension appears like emission in the normal plane; the angle θ in equations (1) and (2) is constrained to the value $\pi/2$ for electric and magnetic fields in any space direction. This means that in the integrated energy of radiation of one cycle in equation (7), the factor 2/3 in the power density distribution is replaced by 1.

A quantum emitter, a hypothetical ideal dipole in the fourth dimension ($z_0 = z_4 = \lambda$), in which a single oscillation cycle of a unit charge ($N = 1$) results in the emission of one energy quantum in one cycle of radiation $E_{0\lambda} = hf$, can be expressed as

$$\begin{aligned} E_{0\lambda} &= \chi_\lambda \left(2\pi^3 e^2 \mu_0 c\right) f = \chi_\lambda \cdot 5.99695618 \cdot 10^{-34} \cdot f \\ &= h\,f = 6.626068765 \cdot 10^{-34} \cdot f \end{aligned} \tag{9}$$

The numerical values e, μ_0, h, and c equation (9) are based on CODATA 1998 recommended values. The constant χ_λ obtains the numerical value

$$\chi_\lambda \approx 1.104905316 \tag{10}$$

χ_λ combines the effects of the local geometry of space on the local velocity of light and a possible geometrical factor related to a dipole in the fourth dimension. Applying equation (9), Planck's constant can be expressed as

$$h = 2\pi^3 \chi_\lambda e^2 \mu_0 c \tag{11}$$

which expresses Planck's constant in terms of the dimensionless constant χ_λ, the unit charge e, the vacuum permeability μ_0, and the velocity of light c. For a unified expression of energies we rewrite equation (9) as

$$E_{0\lambda} = hf = h_0\, f\, c = \frac{h_0}{\lambda} c^2 = c\left|\mathbf{p}\right| = m_{0\lambda} c^2 \tag{12}$$

where h_0 is defined as the *intrinsic Planck's constant* with dimensions of [kg·m] instead of [kgm^2/s] of the traditionally defined Planck's constant

$$h_0 \equiv \frac{h}{c} = \chi_\lambda \cdot 2\pi^3 e^2 \mu_0 = 2.210219 \cdot 10^{-42} \quad [\mathrm{kg \cdot m}] \tag{13}$$

and $m_{0\lambda}$ is the mass equivalence of a quantum of radiation

$$m_{0\lambda} = \frac{h_0}{\lambda} \quad [\mathrm{kg}] \tag{14}$$

Applying the intrinsic Planck's constant, the momentum of a quantum of radiation with wavelength λ can be expressed as

$$p_{0\lambda} = \frac{h_0}{\lambda} c = h_0 f = m_{0\lambda} c \tag{15}$$

Equation (14) relates the wavelength to the mass equivalence of a quantum of radiation

$$\lambda = \frac{h_0}{m_{0\lambda}} \tag{16}$$

As shown by equations (12) to (16), the intrinsic Planck's constant is related to the wavelength of radiation rather than to the momentum of radiation, which is how the traditional Planck's constant is related.

1.3. The fine structure constant

Application of the intrinsic Planck's constant h_0 to the traditional definition of the fine structure constant α gives the expression of the fine structure constant in the form

$$\alpha \equiv \frac{e^2}{2h\varepsilon_0 c} = \frac{e^2 \mu_0 c}{2h} = \frac{e^2 \mu_0 c}{2h_0 c} = \frac{e^2 \mu_0}{2h_0} \tag{17}$$

which shows that the fine structure constant is not a function of the velocity of light. By applying equation (13) in equation (17), the fine structure constant obtains the form

$$\alpha = \frac{e^2 \mu_0}{2 \cdot \chi_\lambda \cdot 2\pi^3 e^2 \mu_0} = \frac{1}{4\pi^3 \chi_\lambda} \simeq 7.297352533 \cdot 10^{-3} \simeq \frac{1}{137} \tag{18}$$

which shows α as a purely mathematical, dimensionless constant without connections to any physical constants.

1.4. Unified expression of electromagnetic energy

Equation (12) shows the energy of a cycle of electromagnetic radiation emitted by a single transition of a unit charge in a point source. The energy of a cycle of radiation emitted by a transition of N unit charges is

$$E_\lambda = c\left|\mathbf{p}_\lambda\right| = N^2 \frac{h_0}{\lambda} c^2 = m_\lambda c^2 \tag{19}$$

where m_λ is the mass equivalence of the a cycle of radiation. By applying the vacuum permeability μ_0 or the fine structure constant α, the Coulomb energy can be expressed as

$$E_{\mathrm{EM}} = -\frac{q_1 q_2}{4\pi\varepsilon_0 r} = -N_1 N_2 \frac{e^2 \mu_0}{4\pi r} c^2 = -N_1 N_2 \alpha \frac{h_0}{2\pi r} c^2 = -m_{\mathrm{EM}} c^2 \tag{20}$$

where

$$m_{\mathrm{EM}} = \left| \frac{q_1 q_2 \mu_0}{4\pi r} \right| \tag{21}$$

has the dimension of mass [kg] and is referred to as the mass equivalence of an electromagnetic energy object. As illustrated by equations (19) and (20), electromagnetic energy both as radiation and as Coulomb energy obtains a form identical to the expression of rest energy of a mass object.

1.5. Energy states of hydrogen-like atoms

Due to the fundamental nature of the fine structure constant, it is illustrative to express the energy states of atoms in terms of the fine structure constant rather than in terms of Rydberg's constant R. The standard non-relativistic solution of energy states of electrons in a hydrogen-like atom is solved from Schrödinger's equation as

$$E_{Z,n} = R \cdot hc \left(\frac{Z}{n} \right)^2 = \frac{m_e e^4}{8\varepsilon_0^2 h^2} \left(\frac{Z}{n} \right)^2 \tag{22}$$

where m_e is the mass of an electron, e is the unit charge of the electron, Z is the number of protons in the atom, and n is a positive integer. By applying the fine structure constant defined in equation (17), equation (22) can be expressed in the form

$$E_{Z,n} = \frac{\alpha^2}{2} \left(\frac{Z}{n} \right)^2 m_e c^2 \tag{23}$$

where m_e is the rest mass electron (corrected with the effect of the nucleus mass M_N $[1/(1+m_e/M_N)]$), and α is the fine structure constant defined in equation (17). The expression given in equation (23) is of special importance when drawing conclusions from the effects of the novel interpretation of a quantum on the rest energy of an electron and the energy states and characteristic emission frequencies of atoms.

The successful interpretation of a point source as a dipole in the fourth dimension suggests the interpretation of space as three dimensional environment moving at velocity c in a fourth dimension with metric nature. In such an interpretation the rest energy of mass appears as the energy of motion mass possesses due to the motion of space. Conservation of total energy in space means that all velocities in space become related to the velocity of space in the fourth dimension. As a further consequence, the local rest energy of mass appears a function of local motion and gravitation, which in equation (23) means that the energy states and the characteristic emission frequencies of atoms become functions of the local motion and gravitation. In fact, the effect of motion and gravitation on locally "available" rest energy converts Einsteinian spacetime with proper time and distance to dynamic space in absolute time and distance [1,2].

2. SPACE AS SPHERICALLY CLOSED SURFACE OF A 4-SPHERE

2.1 Momentum of mass due to the motion of space in the fourth dimension

A fourth dimension of metric nature makes it possible to describe three-dimensional space as a closed "surface" of a 4-sphere expanding at velocity c in a zero-energy balance with the gravitation of the structure in the direction of the 4-radius as described in the Dynamic Universe approach [1,2]. In such a concept, mass has the meaning of the substance for the expression of energy rather than a form of energy. Mass at rest in space has momentum $\mathbf{p}_4 = m\mathbf{c}_4$ due to the motion of space in the fourth dimension, and like for radiation propagating at velocity $c = c_4$ in space, the energy of motion becomes equal to $E = c|\mathbf{p}_4|$ (see Figure 2).

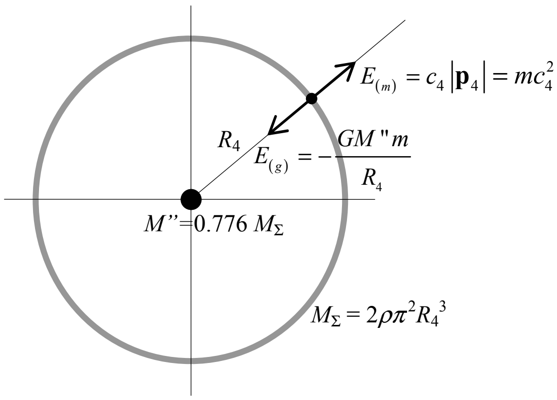

Figure 2. Space as a spherically closed structure. The barycenter of the structure is in the center of the 4-sphere. Integrated gravitational energy of mass m in spherically closed space can be expressed with the aid of the mass equivalence $M" = 0.776 \cdot M_\Sigma$ of space, where M_Σ is the total mass in space.

The expansion velocity c_4 of space in the direction of the R_4 is determined by a zero energy balance between the energies of motion and gravitation of the 4-sphere

$$c_4 = \pm\sqrt{\frac{GM"}{R_4}} = \pm\sqrt{\frac{GI_g M_\Sigma}{R_4}} \tag{24}$$

where G is the gravitational constant, c_4 the velocity in the direction of the radius R_4 of the 4-sphere, and $M" = I_g \cdot M_\Sigma$ the mass equivalence of the total mass M_Σ in space. The factor $I_g = 0.776$ comes from the integration of the gravitational energy of a 4-sphere. Conservation of energy in interactions in space requires that the maximum velocity obtainable in space is equal to the expansion velocity c_4, which means that $c_0 = c_4$ is the velocity of light in hypothetical homogeneous space. *The velocity of light is not an independent physical constant but bound to the velocity of space in the direction of the 4-radius.*

2.2 The effect of local gravitation and motion on the rest energy of an object

In the Dynamic Universe approach, the energy of mass due to the momentum in the direction of the 4-radius of space is $E_0 = c_0|\mathbf{p}_4|$, which is the rest energy of mass at rest in hypothetical homogeneous space, the primary energy of mass in space. Conservation of the primary energy in interactions in space means that an increase of momentum in space is associated with a reduction of the momentum the mass object possesses in the fourth dimension. In a detailed analysis [1,2,5] the rest energy of mass object m in space can expressed as

$$E = c_0 mc \tag{25}$$

where c_0 is the velocity of light in hypothetical homogeneous space equal to the velocity of the expansion of space in the 4-radius of the structure, c is the local velocity of light which is reduced due to tilting of space close to local mass centers. Taking into account the system of n cascaded gravitational frames in space the local velocity of light can be expressed as

$$c = c_0 \prod_{i=1}^{n} (1 - \delta_i) \tag{26}$$

Mass m in equation (25) is the rest mass "available" in the n:th local energy frame

$$m = m_0 \prod_{i=1}^{n-1} \sqrt{1 - \beta_i^2} \tag{27}$$

where m_0 is the rest mass of the object at rest in hypothetical homogeneous space. Velocity β_{n-1} (= v_{n-1}/c_{n-1}) means the velocity on the n:th frame (as an energy object) in the (n–1):the frame and δ_i is the gravitational factor of the object in the i:th frame

$$\delta_i = \frac{GM_i}{r_i c^2} \tag{28}$$

2.3 Characteristic emission and absorption frequencies and wavelengths of atoms

Application of equations (25), (26), and (27) in equation (23) allows the expression of the Balmer's formula for characteristic frequencies to be expressed as

$$f_{(n1,n2)}=\frac{\Delta E_{(n1,n2)}}{h_0 c_0}=Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]\frac{\alpha^2}{2h_0}m_e c=f_{0(n1,n2)}\prod_{i=1}^{n}\left(1-\delta_i\right)\sqrt{1-\beta_i^2} \tag{29}$$

where $f_{0(n1,n2)}$ is the frequency of the transition for an atom at rest in hypothetical homogeneous space

$$f_{0(n1,n2)}=Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]\frac{\alpha^2}{2h_0}m_{e(0)}c_0 \tag{30}$$

As shown by the second form of equation (29), the characteristic frequency is directly proportional to the local velocity of light, which means the velocity of light is observed as constant in local measurements with an atomic clock. The velocity of the expansion of space, $c_0 = c_4$, is a function of the time from singularity. Accordingly, the velocity of light and the frequency of atomic oscillators slow down equally with the expansion of space.

Balmer's formula for characteristic wavelengths obtains the form

$$\lambda_{(n1,n2)}=\frac{c}{f_{(n1,n2)}}=\frac{c_0}{f_{0(n1,n2)}}\frac{\prod_{i=1}^{n}\left(1-\delta_i\right)}{\prod_{i=1}^{n}\left(1-\delta_i\right)\sqrt{1-\beta_i^2}}=\frac{\lambda_{0(n1,n2)}}{\prod_{i=1}^{n}\sqrt{1-\beta_i^2}} \tag{31}$$

which shows that unlike the characteristic frequencies, the characteristic wavelengths of atoms are not a function of the velocity of light. By applying the Bohr radius $a_{0(0)}$, the characteristic wavelength of atoms can be expressed as

$$\lambda_{(n1,n2)}=\frac{4\pi a_0}{\alpha Z^2\left[1/n_1^2-1/n_2^2\right]} \tag{32}$$

which shows that the wavelength emitted is directly proportional to the Bohr radius of the atom. Equation (32) is just another form of Balmer's formula, which does not require any assumptions tied to the nature of the fourth dimension or the motion of space. Equation (32) also means that, like the dimensions of an atom, the characteristic emission and absorption wavelengths of an atom are unchanged in the course of the expansion of space.

When applied in a single frame equation (29) can be expressed as

$$f_{\delta,\beta}=f_{0,0}\left(1-\delta\right)\sqrt{1-\beta^2}\approx f_{0,0}\left(1-\delta-\frac{1}{2}\beta^2-\frac{1}{8}\beta^4+\frac{1}{2}\delta\beta^2\right) \tag{33}$$

which for the first order of β^2 and δ is the same as the corresponding equation derived in the general relativity theory for an oscillator moving in a gravitational frame

$$f_{\delta,\beta(GR)}=f_{0,0}\sqrt{1-2\delta-\beta^2}\approx f_{0,0}\left(1-\delta-\frac{1}{2}\beta^2-\frac{1}{8}\beta^4-\frac{1}{2}\delta\beta^2-\frac{1}{2}\delta^2\right) \tag{34}$$

In a constant gravitational potential characterized by gravitational factor δ_A, equation (33) obtains the form

$$f_{\beta}=f_{0,0}\left(1-\delta_A\right)\sqrt{1-\beta^2}=f_{\delta A,0}\sqrt{1-\beta^2} \tag{35}$$

which shows the effect of motion on the frequency. Equation (35) is formally identical to the corresponding result of special relativity. However, instead of relying on the concept of proper time and a velocity relative to an observer, equation (35) relies on the on the effect of the velocity on the characteristic frequency through the effect of a reduced rest energy of electrons in equation (29). The velocity in equation (35) means velocity relative to the state of rest in the local energy system where the velocity has been obtained; in an accelerator it means the state of a non-accelerated object.

2.4 Gravitational shift of electromagnetic radiation

As shown by equations (29), (33) and (35) the frequencies of atomic oscillators are functions of the gravitational potential. As shown by equation (31) the wavelength of the radiation emitted by an atomic oscillator at different gravitational potentials is unchanged because of the equal changes in the frequency and the velocity of light.

The frequency of electromagnetic radiation passing from one gravitational potential to another, the number of cycles (or quanta) transmitted in a time interval is not subject to a change during the transmission. The wavelength of radiation sent from a different gravitational potential, however, is changed due to the difference in the velocity of light in different gravitational potentials (see Figure 3).

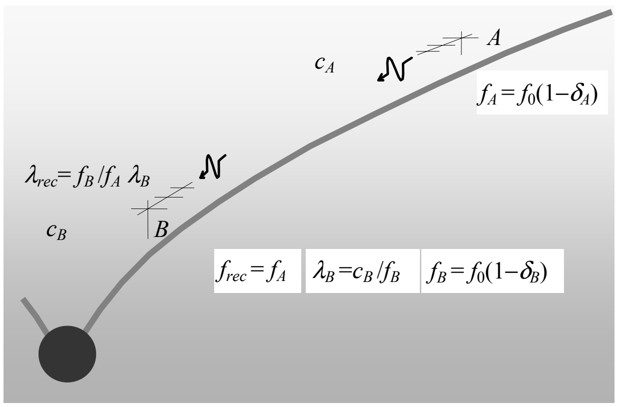

Figure 3. The velocity of light is lower close to a mass center, $c_B < c_A$, which results in a decrease of the wavelength of electromagnetic radiation transmitted from *A* to *B*. Accordingly, the signal received at *B* is blueshifted relative to the reference wavelength observed in radiation emitted by a similar transmitter in the δ_B-state. The frequency of the radiation, the number of quanta in a time interval, is unchanged.

2.5 The Doppler effect of electromagnetic radiation

Equation (30) allows the derivation of the Doppler effect of electromagnetic radiation by combining the effect of motion on the frequency and wavelength in equations (26) and (28) with a classical wave mechanical procedure. In a general form, the frequency transmitted from an oscillator $A(\delta_A,\beta_A)$ to a receiver (reference oscillator) $B(\delta_B,\beta_B)$ is expressed as

$$f_{A(B)} = f_B \frac{\prod_{j=k+1}^{n} \left(1-\delta_{Bi}\right)\sqrt{1-\beta_{Bi}^2}\left(1-\beta_{jB(\mathbf{r})}\right)}{\prod_{i=k+1}^{m} \left(1-\delta_{Ai}\right)\sqrt{1-\beta_{Ai}^2}\left(1-\beta_{iA(\mathbf{r})}\right)} \tag{33}$$

where $\beta_{iA®}$ is the component of the velocity of *A* in the direction of the distance vector $\mathbf{r}_{A,}$, and $\beta_{jB®}$ is the component of the velocity of *B* in the direction of the distance vector $\mathbf{r}_{A,B}$, in the *i*:th and *j*:th frame, respectively.

3. CONCLUSIONS

The solution given by Maxwell's equations for the energy of a single oscillation cycle of a unit charge in a dipole in the fourth dimension gives a natural interpretation to the nature of a quantum as the minimum dose of electromagnetic radiation. The interpretation of a point source as a dipole in the fourth dimension becomes obvious if we give the fourth dimension a metric meaning instead of considering it a time-like dimension of the Einsteinian spacetime. A fourth dimension of a metric nature makes it possible to describe three-dimensional space as a closed "surface" of a 4-sphere expanding at velocity *c* in a zero-energy balance with the gravitation of the structure in the direction of the 4-radius [1,2].

Spherically closed dynamic space converts Einsteinian spacetime in dynamic coordinates to dynamic space in absolute coordinates. The dynamic perspective to space became quite natural since the observations of Edwin Hubble which were not available in early 1900's when the spacetime concept was created. Also, many contemporary questions related to atomic clocks and GPS satellites are easier to tackle and understand on the basis of the dynamic approach studied in detail in the Dynamic Universe theory.

The Dynamic Universe theory actually introduces a paradigm shift comparable to that of Copernicus when he removed the centre of universe from Earth to the Sun. In the present perspective, the universe is revealed to be a four dimensional entity which orders space to appear as the surface of a four dimensional sphere. This sphere, the three-dimensional space, is not held static by the famous cosmological constant, but it is expanding because of an overall zero energy balance between motion and gravitation. Conservation of the total energy in space also links local motion and gravitation to the rest energy of objects allowing the build-up of localized energy structures and material objects. The same pattern makes the ticking frequency of atomic clocks a function of the gravitational state and motion of the clock.

In addition to the nature of quantum as the minimum dose of electromagnetic radiation, Mach's principle, the nature of inertia, and the rest energy of matter, this comprehensive framework gives precise predictions to recent observations on the redshift and magnitude of distant supernova explosions without a need to postulate dark energy or accelerating expansion of space. It also explains the Euclidean appearance of distant space and the apparent discrepancy between the ages of oldest stars obtained by radioactive dating and the age of expanding space, which has remained a mystery.

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