Light Absorption Under the Action of Gravitation Field

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Abstract

The analysis of energy transfer between the electromagnetic wave and the gravitation field is presented. In case of accounting for the imaginary part in the relation for the refractive index of space filled with the gravitation field, the effect of electromagnetic wave absorption induced by this field is possible. The process of energy transfer between the γ-quantum and the gravitation field is described. Interaction of the γ-quantum with the gravitation field is shown to lead to a lose of the γ-quantum energy and an increase in the gravitation mass. It is demonstrated that, in case of the gravitation field of collapsed star having the mass compared with the solar mass, the γ-quantum energy needed for creating the additional mass equal to the electron one should be only W=1.32×10^5eV. The equation for the gravitation radius, which is derived following from the relation for electromagnetic wave polarization, with accounting for its imaginary part responsible for the absorption and assuming that the absorption coefficient of the black holes is equal to unity, turns out to be the same as the equation obtained on the basis of general relativity theory.

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Background

Description of light propagation in a flat space near a massive body, based on introducing distributed dielectric permittivity (or refractive index) of the space treated as a matter, has been attempted long ago, probably in 1921 [1]. Since then, the interest to this type of description has sometimes reappeared in the literature. Interaction of electromagnetic wave with the gravitation field of spherical mass has been considered in the works by *R.H.Dicke* on the basis of *Newton* and *Maxwell* equations (see, e.g., [2]). The approach of a polarizable vacuum for description of phenomena considered usually in terms of curved space-time, has been suggested by *H.E.Puthoff* [3]. Similar description offered by *K.Nandi and A. Islam* [4], *Evans* [5] and *Fernando de Felice* [6] for treating optical phenomena in the gravitation field has been linked to optical-mechanical analogy between a general relativity and a refractive medium characterized with some effective refractive index. The relations for the dielectric permittivity or the refractive index change near the spherically symmetric mass, obtained in all the mentioned works have the same form and the relations for the dielectric permittivity are functions of the distance from the mass centre. For example, the relation taken from [3] is as follows:

$$\varepsilon = 1 + \frac{2GM}{rc_o^2} + \frac{1}{2}\left(\frac{2GM}{rc_o^2}\right)^2 + \dots, \qquad (1)$$

where G is the gravitation constant, M the mass and r the distance from the origin located at the centre of the mass. Let us notice that, at first blush, this relation does not include any constitutive coefficients that could characterize the space considered as a matter and so link the gravitation field strength $\vec{g}_k = \left(GM/r^2 \right) \vec{r}_k$ ($\vec{r}_k$ being the unit vector) with the refractive index. On the other side, one can remember the so-called parametric optical effects consisting in the refractive index or the optical-frequency dielectric impermeability constant ($B_{ij} = \left(1/n^2 \right)_{ij}$) changes under the influence of electric (E_k, E_l) and magnetic (H_k, H_l) fields or mechanical stresses σ_{kl}:

$$\begin{aligned} \Delta B_{ij} &= r_{ijk} E_k + R_{ijkl} E_k E_l + \\ &+ \xi_{ijkl} H_k H_l + \pi_{ijkl} \sigma_{kl} \end{aligned}, \qquad (2)$$

where r_{ijk} represents a polar third-rank tensor with the internal symmetry $[V^2]V$, R_{ijkl} and π_{ijkl} polar fourth-rank tensors with the symmetry $[V^2]^2$ and ξ_{ijkl} fourth-rank axial (or pseudo-) tensor with the symmetry $\varepsilon[V^2]^2$. Presentation of dielectric impermeability changes in terms of such the relation is quite convenient because the corresponding coefficients r_{ijk}, R_{ijkl} , π_{ijkl} and ξ_{ijkl} depend on the symmetry of matter. Moreover, lowering of material symmetry under the action of every field should obey the *Curie* principle and depend on the field symmetry, while the availability of certain property of the matter is governed by the *Neumann* principle. Then one can ask the following questions: (a) is it possible to derive similar relation between the effective refractive index of the space and the gravitation field strength, (b) which kind of constitutive tensors would play a role of coupling coefficients in such the relation, and (c) which symmetry properties would obey these coefficients? These problems have been solved in our previous paper [7]. Namely, we have suggested in [7] presenting the relation analogous to Eq. (1) as

$$\begin{aligned} B_{ij} &= 1 \mp 4\sqrt{GM/c_0^4}\,(g^{1/2}) - \\ &-7\left(\sqrt{GM/c_0^4} \right)^2 g + ... \end{aligned} \qquad (3)$$

or, in terms of the refractive index,

$$n = 1 \pm 2\sqrt{\frac{G}{c_0^4} M}\,(g^{1/2}) + \frac{3}{2}\frac{G}{c_0^4} Mg + \dots . \qquad (4)$$

This has led to some interesting conclusions. Some of them are as follows: (a) the light velocity depends upon the gravitation field strength and approaches c_0 value only if the gravitation field strength tends to zero; (b) the quantity G represents in fact material (constitutive) coefficients of the flat space (or the corresponding optical medium) and should therefore obey the *Neumann* principle; (c) being a scalar action, gravitation field of a spherical mass cannot lead to appearance of anisotropy; and (d) hypothetical lowering of initially isotropic symmetry of space by the gravitation or the other fields can give rise to appearance of tensorial properties of the coefficient G, the *Hubble* constant and the time. In frame of this description, the time plays a role of spatial property. In other word, due to the *Curie* principle, the symmetry group of flat space should depend on the field configuration and, following the *Neumann* symmetry principle, it should be a subgroup of symmetry group of the time. One of the most important conclusions following both from [7] and the other mentioned studies is that the field of electromagnetic wave interacts with the gravitation field in flat 3D space. Thus, it is possible to describe the well-known phenomena like bending of light in the gravitation field of massive body, a red shift [2], etc., starting from this interaction. Then the principles of electromagnetic theory of matter could be spread more completely in order for describing the processes of electromagnetic wave interaction with the gravitation field. The relations (3) and (4) describe refraction properties and, in some changed form, they can also deal with a reflection. Let us now remind a fact known from the basic optics: the refraction is related to the absorption at some frequencies ω_0, through the *H.Kramers* and *R.Kroning* relations. In other words, the real part of the high-frequency dielectric permittivity (or the refractive index) should approach unity, when the light absorption at these resonant frequencies ω_0 is absent. It means that if Eqs. (3) and (4) include the terms, which give the refractive index differing from unity, these equations should necessarily include an imaginary part, which is responsible for absorption at some resonant frequencies ω_0. One can imagine that such unusual cosmic objects as black holes might be considered, from the electromagnetic viewpoint, as a completely absorbing matter, the absorption appearing owing to the action of their strong gravitation field. Thus, it would be reasonable to involve the absorption in a usual way, by adding imaginary part of the refractive index in Eqs. (3) and (4).

Energy exchange between the electromagnetic wave and the gravitation field

With accounting of light absorption, the relation for the polarization should contain both real and imaginary parts[1] according to

$$P^{(\omega)} = E^{(\omega)} - \left(4\sqrt{\beta M}\sqrt{|g|} \pm i4\sqrt{\beta M}\sqrt{|g|}\right)E^{(\omega)}, \quad (5)$$

or, for the refractive index,

$$n = 1 + 2\sqrt{\beta M}\sqrt{g} \pm i2\sqrt{\beta M}\sqrt{g}\,. \quad (6)$$

Since we consider light propagation in a medium filled only with the gravitation field, relations (5) and (6) cannot include any material coefficients, except for $\beta = \frac{G}{c_0^4}$ only. The real part in Eq. (6) describes the change in the refractive index of the space (or the polarizable vacuum, in frame of the definition [3]) under the action of gravitation field, whereas the imaginary part occurred in this relation corresponds to absorption or amplification of electromagnetic radiation with the gravitation field. Let us analyse the third term in the r.h.s. of Eq. (6), being the extinction coefficient $i\chi = i2\sqrt{\beta M}\sqrt{g}$. When describing the matter, it can be presented as a sum of the absorption and scattering coefficients. As a first approximation, let us neglect the latter. Then the extinction coefficient is reduced to the absorption one. If the black holes are completely absorbing media, their absorption coefficient κ should equal to unity. Thus, one can write out the following relation for the extinction coefficient,

$$\chi = \kappa = 2\sqrt{\beta M}\sqrt{g} = 1\,. \quad (7)$$

Introducing $\beta = \frac{G}{c_0^4}$ and $g = \frac{GM}{R^2}$ into Eq. (7), one can calculate the radius of the collapsed star, for which all the optical radiation will be absorbed under the action of its gravitation field. This radius is equal to

$$R_S = \frac{2GM}{c_0^2}\,. \quad (8)$$

As one can see, we have arrived at the *Schwarzschild* radius[2], following from the assumption of a full light absorption. It means that the approach common for the continuum-matter electromagnetism is valid for the case of light propagation in space in the presence of gravitation field and it leads to the same result as the general relativity (GR)[3]. Most probably, the black holes may prove to be only a mathematical abstraction, to which any massive body is approaching though never reaches such the state. This implies that the absorption coefficient induced by the gravitation field will never reach a unit value, remaining in the range

[1] The exponential presentation of Eq. (5) is $P^{(\omega)} = E^{(\omega)} \pm 4\sqrt{2\beta Mg}e^{i\omega_0 t}E^{(\omega)}$, where $\omega_0 t$ is the light phase delay.

[2] It is worth noticing that the real part of the refractive index should be equal exactly to 2 at $R=R_s$ according to the relation (6).

[3] The equation for the *Schwarzschild* radius may be derived not only with using the GR principles and the *Schwarzschild* metrics, but also following from the relation for the escaping light velocity and the *Newtonian* gravitation equation.

of 0 – 1. For instance, X-ray sources are very close to the black hole (or the neutron star) state, being able to produce gravitation fields high enough for inducing a sufficient light absorption. In this case, the energy of the electromagnetic wave (or the quantum of light) should be transferred to the other kind of energy. Let us analyse this process in a more detail.

The electromagnetic wave energy is usually presented by the well-known equation $W = \frac{1}{2}\varepsilon_0 E_0^2$ and it can be rewritten as $W = \frac{1}{2}\varepsilon_0 P_0^2$, since we have $\varepsilon = \mu = 1$ for the vacuum. The part of the polarization amplitude responsible for the absorption or amplification of electromagnetic wave is then

$$\Delta P_0 = i4\sqrt{\beta M g}\,E_0 . \qquad (9)$$

The electromagnetic wave energy absorbed by the gravitation field is then written as

$$\left|\Delta W\right| = 8\varepsilon_0 \beta M g E_0^2 . \qquad (10)$$

Presenting the single γ-quantum energy as $W = h\nu = \frac{1}{2}\varepsilon_0 E_0^2$, one can replace the quantity $E_0^2 = \frac{2h\nu}{\varepsilon_0}$ in Eq. (10) with

$$\left|\Delta W\right| = 16\beta M g h\nu . \qquad (11)$$

Eq. (11) describes the energy exchange between the electromagnetic radiation and the gravitation field. For example, the energy of the gravitation field will increase when the energy is transferred from the electromagnetic wave to the gravitation field. This process is equivalent to increase in the gravitation mass. Let us derive the relation between the mass increase and the γ-quantum energy. To do this, we are to use the equation for the relativistic energy $\Delta W = \Delta m c_0^2$ and simply rewrite Eq. (11):

$$\Delta m c_0^2 = 16\beta M g h\nu \quad (12)$$

Finally, we obtain

$$\Delta m = \frac{16\beta M g h\nu}{c_0^2} = \frac{16 G M g h\nu}{c_0^6} . \qquad (13)$$

Thus, the interaction of the γ-quantum with the gravitation field can lead to the mass creation. Let us estimate which energy should possess the γ-quantum for creating the mass equal, e.g., to the electron mass (m_e=9.1093897×10^{-31}kg), in the gravitation field of the Sun on its surface. Here we take the Sun mass value M=1.991×10^{30}kg and the gravitation field strength at the Sun surface g=273.98m/s^2. Calculation according to the formula

$$\Delta W = h\nu = \frac{m_e c_0^6}{16 G M g} \qquad (14)$$

gives a quite large γ-quantum energy, W=7.09×10^{15}eV. Nonetheless, in the hypothetical case when the Sun becomes a black hole, with the *Schwarzschild* radius R=3×10^3m, its gravitation field will become drastically large (g=1.47×10^{13} m/s^2). The γ-quantum energy needed for creating the mass, which is equal to the electron mass, is then only W=1.32×10^5eV. This value is located in a spectral range usual for γ-quanta. Moreover, if we turn to the real objects such as X-ray sources or neutron stars, we find that their masses are sometimes several times larger than the solar mass. As a result, these cosmic objects can really produce an additional mass while absorbing electromagnetic radiation and so increase this way their own mass. In relation to this, it is interesting to remind that, according to the recent data, the Universe consists mainly of a "dark matter", which can probably be a product of the mass increasing due to the light absorption.

Conclusions

It has been shown that accounting of imaginary part occurred in the relation for the refractive index of space filled with the gravitation field enables one to consider the effect of electromagnetic wave absorption induced by this field. The process of energy transfer between the γ-quanta and the gravitation field has been described and it has been shown that the interaction of γ-quantum with the gravitation field can lead to loses in the γ-quantum energy and increase in the gravitation mass. For example, it has been demonstrated that, in case of the gravitation field of collapsed star such as the Sun, the γ-quantum energy needed for creating the additional mass equal to the electron mass is only W=1.32×10^5eV. The equation for the *Schwarzschild* radius is derived, following from the relation for polarization of electromagnetic wave, accounting the imaginary part responsible for the absorption and, finally, assuming that the absorption coefficient of black holes should be equal to unity. This equation for the gravitation radius has proven to be the same as the equation obtained on the basis of the GR theory.

The subsequent results on the subject will be reported in a forthcoming paper.

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