OPTIC-MECHANICAL ANALOGY AND GRAVITATIONAL EFFECTS IN THE EXTENDED SPACE MODEL

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Abstract

New approach to the description of a gravitation using analogy between the optical and mechanical phenomenon is advanced. For this purpose in extended (1+4)-dimensional space $G(1,4)$ the gravitational effects are considered: the speed of escape, red shift, radar echo, deviation light and perihelion precession of Mercury. It is shown, that methods of the Extended Space Model (ESM) give the same outcomes, as General Theory of Relativity (GR). The various ways of introduction of refraction index are discussed, which appropriate to the gravitational field.

1. INTRODUCTION

It is known, that between the mechanical and optical phenomena there is a certain likeness, which historically was exhibited that a set of the optical phenomena managed uniformly well to be described both within the framework of wave, and within the framework of the corpuscular theories. In particular, motion of a beam of light in an inhomogeneous medium in many respects similar to motion of a material particle in a potential field [1]. In the given activity, we shall take advantage of this connection to describe the gravitational phenomena. Will be shown, that it is possible to receive such effects of General Theory of Relativity (GR), as red shift, radar echo, deviation of light and a perihelion precession of a Mercury, using ideas and methods of geometric optics.

In the papers [2-7] the Extended Space Model (ESM) and the electrodynamics in this space was constructed. ESM are by generalization of a Special Theory of Relativity (GR) on (1 + 4) - dimensional space which having the metric (+ - - - -). We designate it as $G(1,4)$. Space of the Minkowski $M(1,3)$ is a subspace of the ESM. The role of the fifth coordinates in space $G(1,4)$ plays an interval in space of the Minkowski $M(1,3)$. We shall designate its by letter $S$.

One of the characteristics of this theory is that in it the rest mass of particles - is a variable and a photon, falling in the medium with the refraction index $n > 1$, acquires nonzero mass. The probability that a photon has nonzero mass is widely discussed both theorists, and experimenters. The review of the last outcomes is contained in [8]. Our approach differs by that in ESM mass of a particle is not constant, and is determined by external effects, which it experiences, theme processes, in which it participates.

According to philosophy of extended space external effects on any object are described as change of refraction index $n$ in a point, where there is a given object. Formally such processes within the framework of our model are described by rotations in extended space $G(1,4)$ [2,6]. One of the main physical problems in ESM is how to compare particular interactions with appropriated to them distributions of an index of refraction. In each separate case, this problem is decided in its own way.

Gravitational field is one of examples of physical objects, to which compares some refraction index. From the very beginning origins, GTR there was a problem of its experimental checking. The majority of observable gravitational effects connected with the optical phenomena and with a behavior of photons in a gravitational field. One of such effects is, in particular - deviation of light in a gravitational field. This deviation can be interpreted as motion of a light ray in environment with an inhomogeneous refraction index. Thus, we can to compare to a gravitational field some index of refraction.

In this paper, we will consider well-known gravitational effects, used for the GR confirmation. In addition, we shall show, that all of them can be described and in frameworks ESM. Let’s mark also, that now attempts in a new way to interpret the gravitational effects are considered by other authors [9-13].
II. ESM FORMALISM

In the Minkowski space $M(1,3)$ to each particle the 4-vector energy-momentum is compared [14]

$$\mathbf{p} = \left( \frac{E}{c}, p_x, p_y, p_z \right).$$  \hspace{1cm} (1)

In the extended space $G(1,4)$ we building it up to 5-vector

$$\mathbf{p} = \left( \frac{E}{c}, p_x, p_y, p_z, mc \right).$$  \hspace{1cm} (2)

For free particles the components of vector (2) satisfy to an equation

$$E^2 = c^2 p_x^2 + c^2 p_y^2 + c^2 p_z^2 + m^2 c^4,$$  \hspace{1cm} (3)

i.e. this vector is isotropic.

Parameter $n$ links speed of light in vacuum $c$ with speed of light in the medium $v = c/n$. By the help of it is possible to define fifth coordinate in space $G(1,4)$. Thus the empty Minkowski space $M(1,3)$ corresponds to $n=1$. In this medium light is gone with speed $c$. Hit of light in medium with $n \neq 1$ is interpreted as an exit of a photon from the Minkowski space and transition of light in other subspace of space $G(1,4)$. Such transition can be described with the help of rotations in space $G(1,4)$. All types of such rotations are investigated in [2,6].

In blank space in a fixed reference system there are two types of various object, with zero and nonzero masses. In space $G(1,4)$ to them there are corresponds 5-vectors

$$\left( \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c}, 0 \right).$$  \hspace{1cm} (4)

$$\left( mc, 0, mc \right).$$  \hspace{1cm} (5)

For simplicity we have recorded vectors (4), (5) in $(1+2)$-dimensional space. The vector (4) describes a photon with zero mass, with energy $\hbar \omega$ and with speed $c$. The vector (5) describes a fixed particle with weight $m$.

At hyperbolic rotations on an angle $\theta$ in the plane (TS) the photon vector (4) will be transformed as follows [2,6]

$$\left( \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c}, 0 \right) \rightarrow \left( \frac{\hbar \omega}{c} \cosh \theta, \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c} \sinh \theta \right) = \left( \frac{\hbar \omega}{c n}, \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c} \sqrt{n^2 - 1} \right).$$  \hspace{1cm} (6)

Because of such transformations there is a particle with mass

$$m = \frac{\hbar \omega}{c^2} \sinh \theta = \frac{\hbar \omega}{c^2} \sqrt{n^2 - 1}.$$  \hspace{1cm} (7)

At these rotations the massive vector (5) will be transformed as follows

$$\left( mc, 0, mc \right) \rightarrow \left( mce^\theta, 0, mce^\theta \right), \hspace{1cm} e^{\theta \pm} = n \pm \sqrt{n^2 - 1}.$$  \hspace{1cm} (8)

At such rotation the massive particle changes mass

$$m \rightarrow m e^\theta, \hspace{1cm} 0 \leq \theta < \infty$$  \hspace{1cm} (9)

and energy, but is saved a momentum.

At a rotation on an angle $\psi$ in a plane (XS) photon vector (4) will be transformed under the law

$$\left( \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c}, 0 \right) \rightarrow \left( \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c} \cos \psi, \frac{\hbar \omega}{c} \sin \psi \right) = \left( \frac{\hbar \omega}{c n}, \frac{\hbar \omega}{c n}, \frac{\hbar \omega}{c n} \sqrt{n^2 - 1} \right).$$  \hspace{1cm} (10)

Thus the photon acquires mass

$$m = \frac{\hbar \omega}{c^2} \sin \psi = \frac{\hbar \omega}{c^2 n}.$$  \hspace{1cm} (11)
and velocity
\[ v = c \cos \psi = \frac{c}{n}. \tag{12} \]

The vector (5) massive particles will be transformed under the law
\[ (mc, 0, mc) \rightarrow (mc, -mc \sin \psi, mc \cos \psi) = \left( mc, -\frac{mc}{n} \sqrt{n^2 - 1}, \frac{mc}{n} \right). \tag{13} \]

Energy of a particle at such transformation is saved, but varies mass
\[ M \rightarrow m \cos \psi = \frac{m}{n}, \tag{14} \]
and momentum
\[ 0 \rightarrow -mc \sin \psi = -\frac{mc}{n} \sqrt{n^2 - 1}. \tag{15} \]

The important property of transformations (6) (10) is that mass of a photon, which it generates, can have both positive and negative sign. It follows immediately from properties of a symmetry of space \( G(1, 4). \) As to particles, which initially had positive mass, after transformations (8), (13) it remains positive.

### III. Refraction Index of a Gravitational Field

Let’s study now a problem of refraction index of a gravitational field. Let there is a dot mass, which gravitational field is described by the Schwarzschild solution. We assume, that the gravitational radius \( r_g \) is small and we shall consider all effects on distances \( r > r_g. \)

In the literature there are two expressions for an index of refraction \( n, \) appropriate to a Schwarzschild field. One of them, we shall name it \( n_1, \) is used in papers of the Okun [15,16] and looks like
\[ n_1(r) = (g_{00})^{-1} = (1 - \frac{r_g}{r})^{-1} \approx 1 + \frac{r_g}{r} = 1 + \frac{2\gamma M}{rc^2}. \tag{16} \]

It is received in the supposition, that in a constant gravitational field the frequency of a photon \( \omega \) remains to a constant, but the wavelength \( \lambda \) and speed \( v \) vary. Other index of refraction \( n_2 \) is possible to receive from the formula of an interval in a weak gravitational field [14]
\[ Ds^2 = (c^2 + 2\varphi)dt^2 - dr^2, \tag{17} \]

Where \( \varphi \) - is a potential of a gravitational field. Supposing \( dr = v dt \) and \( ds^2 = 0, \) we shall receive speed of a photon in the gravitational field
\[ v = c \left( 1 + \frac{2\varphi}{c^2} \right)^{1/2} \approx c \left( 1 + \frac{\varphi}{c^2} \right). \tag{18} \]

Here it is necessary to take into account that a potential of a gravitational field \( \varphi \) - is negative. For a point source of mass \( M \) we have
\[ \varphi(r) = -\frac{\gamma M}{r}. \tag{19} \]

Substituting expression (19) in the formula (18), we receive
\[ v \approx c \left( 1 - \frac{\gamma M}{rc^2} \right). \tag{20} \]

Collins obtained the same formula in another way [17]. He considered particle of mass \( m_0, \) located indefinitely far from a point source of a gravitational field of mass \( M. \) Such particle has energy \( E_0 = m_0c^2. \) At movement on a
distance \( r \) from a source of a field, particles energy will increase up to size 
\[ E = m_0c^2 + \left( \gamma m_0 \right)/r. \]
Collins offers to interpret this change of energy as change of a rest mass in a gravitational field.

\[ m = m_0 \left( 1 + \frac{\gamma M}{rc^2} \right). \tag{21} \]

Then he uses a conservation law of a momentum \( mv = m_0v_0 \) and receives the law of change of speed in a gravitational field

\[ V = v_0 \left( 1 + \frac{\gamma M}{rc^2} \right)^{-1}. \tag{22} \]

Supposing, that this law is distributed also to photons, we receive the formula for change of photons speed in a gravitational field

\[ v = c \left( 1 + \frac{\gamma M}{rc^2} \right)^{-1} \approx c \left( 1 - \frac{\gamma M}{rc^2} \right). \tag{23} \]

It is possible to interpret the formulas (20), (23) as hit of a photon in medium with a refraction index

\[ n_2(r) = 1 + \frac{\gamma M}{rc^2}. \tag{24} \]

In that case, when the speed of a particle \( v \) is comparable to the speed of light \( c \), in the formula (21) it is necessary to take into account relativistic correction to a rest-mass \( m \) and to record it as

\[ M = m_0 \left( 1 + \frac{\gamma M}{rc^2} + \frac{1}{2} \frac{v^2}{c^2} \right). \tag{25} \]

Appropriate refraction index will look like

\[ n'_2(r) = 1 + \frac{\gamma M}{rc^2} + \frac{1}{2} \frac{v^2}{c^2}. \tag{26} \]

Such difference in definition of refraction index of a gravitational field is connected with that the speech in these cases goes about different objects, which differently interact with a gravitational field. In ESM to these situations there corresponds also different rotations in extended space.

**IV. GRAVITATIONAL EFFECTS IN ESM**

1) Speed of escape.

Speed of escape \( v_2 \) is that speed, which should be given to a body located on a surface of the Earth, that it could be deleted from Earth on an indefinitely large distance. Let \( M \) - mass of the Earth, \( m \) - mass of a body located at the Earth surface, and \( R \) - radius of this surface. The expression for the speed of escape is [18]

\[ v_2 = \sqrt{2gR} = \sqrt{\frac{2\gamma M}{R}}. \tag{27} \]

We will receive now formula (27) using ESM methods. Let’s consider a massive particle at rest, which removed to infinite large distance from the Earth. Within the framework of our model such particle is described by isotropic 5-vector of energy-momentum-mass (5). Space motion in gravitational field along an axis \( X \) can compare movement in extended space \( G(1, 4) \) in a plane \( XS \) from a point with refraction index \( n = 1 \) to point with refraction index \( n(r) \). Such motion is described by a rotation (13).

Here rotation angle \( \psi \) express through refraction index \( n \). Thus the massive particle at rest acquires speed

\[ v = c \frac{\sqrt{n^2 - 1}}{n}. \]

As to in this case we consider a motion of a massive body, we assume natural to use refraction index \( n_2 \). Assuming, that it is close to unit, i.e. that
\[1 \gg \varepsilon = \frac{2M}{r c^2},\]  
we receive, that \[v \approx c \sqrt{2 \varepsilon}.\]  
In case, when \(r = R\) - radius of the Earth, the formula (29) coincides with the formula (27) and gives the speed of escape \(v = v_2\).

2) Red shift.

Gravitational red shift usually considered as a change of frequency of a photon in the case of changing of a gravitational field, in which photon is merged. In particular, at decreasing of strength of a field the frequency of a photon also decreases, that is it reddens \([14]\). However Okun offers to recognize that not frequency varies but varies wavelength of a photon, and just it to name as red displacement \([9,10]\). Under our judgment both cases are possible, but they corresponds to different physical situations and are described by different rotation angle \(\psi\) express through refraction index \(n\).

In a general theory of relativity the formula that describes change of light frequency is \([14]\)
\[
\omega = \frac{\omega_0}{\sqrt{g_{00}}} \approx \omega_0 \left(1 + \frac{\gamma M}{rc^2}\right). \tag{30}
\]
Here \(\omega_0\) - frequency of a photon measured in universal time, it remains constant at propagation of a beam of light. And \(\omega\) - frequency of the same photon which measured in its own time. This frequency is various in various points of space. If the photon was emitted by a massive star, near to a star at small \(r\) the frequency of a photon is more, than far from it at large \(r\). On infinity in the flat space, where there is no gravitational field, the universal time coincides with own and \(\omega_0\) there is an observable frequency of a photon.

Let’s consider now same problem from the point of view of ESM.

Within the framework of our model to a photon located in blank space, the isotropic 5-vector (4) is compared. Process of its movement to the point with refraction index \(n\), at which the change it of frequency happens, so also of energy, is described by a rotation in \((TS)\) - plane. At these rotations the photon vector will be transformed se, when \(r = R\) - radius of the Earth, the formula (29) coincides the formula (27) and gives the speed of escape \(v = v_2\). From here it is visible, that \(\omega_0\) - frequency of a photon in vacuum and \(\omega\) - it frequency in a field are connected by a ratio d shift.

\[\text{tionalredshiftusuallyconsideredasachangeoffrequencyofaphotoninthe}
\text{caseofchangingofagravitationalfield,whichphotonismerged.}\]

\[\omega = \omega_0 n_2 = \omega_0 \left(1 + \frac{\gamma M}{rc^2}\right). \tag{32}\]

which coincides the formula (30). Thus in extended space model for red shift is received the same expression, as in general theory of relativity.

In papers \([15,16]\) Okun has offered to consider red shift of a photon as change it of speed, momentum and wavelength, but the frequency was assumed constant. He proceeded from a dispersing ratio for a photon with zero mass in space with the Schwarzchild metric
\[
G^{00} p_0 p_0 - g^{rr} p_r p_r = 0.
\]

The Schwarzchild metric is
\[
G^{00} = (1 - \frac{r_g}{r})^{-1}, \quad g^{rr} = (1 - \frac{r_g}{r}), \quad R_g = \frac{2\gamma M}{c^2}. \tag{33}
\]

Assuming, that \(p_0 = \hbar \omega = \text{const}\), the Okun has received for relation of a momentum \(p_r\) from a radius \(r\) expression
\[
p_r(r) = \frac{\hbar \omega}{(1 - \frac{r_g}{r})^{-1}} = p_r(\infty)n_1. \tag{34}\]
Where \( p_r(\infty) \) - is momentum of the photon at infinity, where the influence of gravitational field is absent.

Using connection between a momentum of a photon and its wavelength \( \lambda(r) \), we receive expression

\[
\lambda(r) = \frac{2\pi}{\omega} v = \frac{2\pi c}{\omega} \left(1 - \frac{r_g}{r}\right) = \frac{2\pi c}{\omega n_1} = \frac{\lambda(\infty)}{n_1}.
\] (35)

For speed of a photon \( v(r) \) the Okun receives expression

\[
v(r) = \frac{\lambda(r) \omega}{2\pi} = c \left(1 - \frac{r_g}{r}\right) = \frac{c}{n_1}.
\] (36)

Let’s look now at transformations (34) - (36) from the ESM point of view.

As the frequency of a photon remains constant, but vary its momentum and mass the appropriate transformation must be described by a rotation in the plane \((X S)\) of the spaces \(G(1,4)\). As the frequency does not vary, we take refraction index \( n_1 \). At such rotation the speed of a photon varies according to the formula

\[
v = c \cos \psi = \frac{c}{n_1}.
\] (37)

This formula coincides the formula (36) for transformation of speed. Being repelled from it is possible to receive the formula (35), assigning change of a wavelength of a photon, when photon hit in a gravitational field. As if to formula (34) naturally we can not to receive it, as to we should use at calculations not a dispersing ratio (32), but curved in \((1 + 4)\)-dimensional Schwarzchild metric analog of a full dispersing ratio of a photon in space \(G(1,4)\)

\[E^2 - c^2 p_x^2 - c^2 p_y^2 - c^2 p_z^2 - m^2 c^4 = 0,\] (38)

From a point of view of our model it is necessary to consider the formula (31) only as first approximation to an exact result. Let’s estimate correction appropriate to that in this model the photon, hitting in area with \( n > 1 \) gains a nonzero mass. For this reason the part of a photon energy can be connected not to frequency, but with the mass. Let’s estimate magnitude of this energy for case, when photon frequency change, in case of incident from a height \( H \) in a homogeneous gravitational field, with acceleration of gravity \( g \) is measured. Such situation was realized in well known Pound and Rebka experiments \[19\]. The energy change which appropriated to such frequency shift, is equal

\[
\Delta E = \left(\frac{\hbar \omega}{c^2}\right) gH.
\] (39)

According to the formula (6) in the case of rotation in plane \((TS)\) the photon gains a mass

\[
m = \frac{\hbar \omega}{c^2} \sqrt{n^2 - 1}.
\] (40)

The difference of potential energies in the point of emission and point of absorption of a photon, which differ by height \( H \), is equal

\[
\delta E = mgH = \left(\frac{\hbar \omega}{c^2}\right) gH \sqrt{n^2 - 1}.
\] (41)

Near to a surface of the Earth refraction index of gravitational field is define by the formula (16). Taking into consideration an inequality (28), we shall receive an evaluation

\[
\delta E = mgH = \left(\frac{\hbar \omega}{c^2}\right) gH \sqrt{n^2 - 1} \approx
\]

\[
\left(\frac{\hbar \omega}{c^2}\right) gH \sqrt{\frac{2\gamma M}{R c^2}} = \left(\frac{\hbar \omega}{c^2}\right) gH \sqrt{\frac{2gR}{c^2}} \approx \left(\frac{\hbar \omega}{c^2}\right) gH (2.5 \cdot 10^{-5}).
\] (42)

We see, that correction to effect connected to emerging of the photons nonzero mass, near to the Earth surface is only \(10^{-5}\) from magnitude of the total effect.

3) Delay of radar echo.
The appearance of radar echo delay is, that the time of light distribution up to some object, and back, can differ in dependence from that, does this light spread in a hollow, or in a gravitational field. Such delay was measured in experiments on location of Mercury and Venus [20]. Such experiments give satisfactory agreement with GR predictions. These experiments also were analyzed in [21]. Here we do not interesting to analysis of these work. We want only to indicate that the analytical expression for magnitude of delay of a radar echo in ESM coincides what is received in GR.

This result can be obtained from the fact that the photon time delay \( \Delta t \) is calculated from only from the photon velocity \( v(t) \) [15,16]. Let’s imagine that we locate the Sun. In this case we have

\[
\Delta t = 2 \left( \int_{r_e}^{r_s} \frac{dr}{v(r)} - \int_{r_e}^{r_s} \frac{dr}{c} \right).
\] (43)

Here \( R_s \) - radius of the Sun, \( r_g \) - gravitational radius of the Sun, and \( r_e \) - distance from the Earth up to the Sun.

Speed of light in a gravitational field is \( v = \frac{c}{n} \). As here we deal with photons, as a refraction index it is necessary to select \( n = n_1 \). Substituting it in (43), we obtain

\[
\Delta t = \frac{4\gamma M}{rc^2} \ln \frac{r_e}{R_s}.
\] (44)

The formula (44) coincides with expression for magnitude of radar echo delay obtained in work [16,21].

4) In general theory of relativity magnitude of deviation angle \( \delta \psi \) of a light beam from a rectilinear trajectory in case of photon motion near to a massive body determine, deciding the eyconal equation which defining trajectory of this beam in a central-symmetrical gravitational field [14]. In this case we receive the answer

\[
\psi = \frac{4\gamma M}{Rc^2}.
\] (45)

Here \( M \) - mass of a body, and \( R \) - distance at which the light beam passes from a field center.

As in this case speech goes about photons motion it is necessary to select \( n = n_1 \). Let’s consider two beams - one passes precisely through an edge of the Sun, and other at a distance \( h \) from it. It is supposed, that \( h \ll R_s < r \). In case of passing by these rays of a linear segment of length \( dx \) the residual of optical paths will be

\[
\delta x = dx n_1(r) - dx n_1(r + h \cos \varphi) =
\]

\[
dx \left(1 - \frac{r_g}{r}\right) - dx \left(1 - \frac{r_g}{r + h \cos \varphi}\right) \approx \frac{r_g h \cos \varphi}{r^2} dx.
\] (46)

To such difference of optical paths there corresponds an angle of a wave front deviation

\[
\delta \varphi \approx \frac{\delta x}{h} = \frac{r_g \cos \varphi}{r^2} dx = \frac{r_g R_s}{R^3} dx = \frac{r_g R_s dx}{(x^2 + R_s^2)^{3/2}}.
\] (47)

Integrating this expression on \( x \) from \( -\infty \) up to \( +\infty \) we shall receive deviation angle

\[
\varphi = r_g R_s \int_{-\infty}^{\infty} \frac{dx}{(x^2 + R_s^2)^{3/2}} = \frac{2r_g R_s}{R^3} = 4\gamma M R_s c^2 R_s c^2,
\] (48)

Which coincides with an angle (45).

5) Perihelion precession of Mercury

One more classical GR effect is the perihelion precession of Mercury. It arises due to a space curvature the Newton’s law of an attraction is deformed. It reduces that the trajectory of a partile becomes nonclosed, and after of each rotation it the perihelion precessed at some angle. The magnitude of this rotation is determined by the law of interaction of a central mass \( M \) and mass \( m \) particles rotated around it. In case of a Schwarzchild potential the force of interaction of these masses is [22]

\[
F(r) = -\frac{\gamma M m}{v^2 \sqrt{1 - r_g / r - v^2 / c^2}}.
\] (49)
Here $r_g$ - gravitational radius of mass $M$, and $v$ - velocity of moving at the orbit partile with mass $m$. The Mercury velocity of motion at the orbit around the Sun is equal approximately 48 km/s, that gives magnitude of the relativistic correction $v^2/c^2 \approx 5 \times 10^{-8}$.

The gravitational correction has magnitude $r_g/r \approx 5 \times 10^{-8}$ and it is comparable with relativistic correction. It is possible to consider, that in the formula (49) masses of a partile $m$ depend on a distance and velocity. But as both these corrections are small, the total transformation of mass $m$ can be write as

$$
m \rightarrow m \left(1 + \frac{\gamma M r c^2}{2 c^2} \right).
$$

The calculation with use of force (49) and including into account an approximation (50) gives an value of perihelium precession of Mercury close to observed. Let’s consider now this case in ESM framework.

We have a partile with a nonzero mass were in a gravitational field. As the partile has a nonzero mass, it is necessary to use the refraction index $n_2$. This is similar to our way of estimation of the escape velocity. As the relativistic correction in this case cannot be neglected, we shall use an index of refraction $n'_2$, which is determined by the formula (26). However, now "motion" of a partile from area with refraction index $n = 1$ to the area with refraction index $n'_2$ does not defined by real motion particle in space. Such "motion" determined by changing of the force magnitude, operating on a partile, i.e. this is the case of particle energy modification. Therefore in this case it is necessary to use a (TS) rotation in extended space $G(1,4)$.In the case of such rotation the massive vector (5) will be transformed in accordance with (8). Thus in case of such rotation the massive partile changes the mass

$$
m \rightarrow m e^{\theta}, \quad 0 \leq \theta < \infty
$$

That fact, that in the formula (8) both signs have a direct physical sense, means, that in case of such transformation from one partile with a mass $m$ there can origin two partiles with different masses.

$$
m \rightarrow m_+ = me^{\theta_+} = m(n + \sqrt{n^2 - 1}).
$$

$$
m \rightarrow m_- = me^{\theta_-} = m(n - \sqrt{n^2 - 1}).
$$

We shall assume, that in a macroscopic massive body there is an equal number of partiles which converts under the laws (52), (53), and consequently we shall use the average law of transformation

$$
M \rightarrow mn_2 = m \left(1 + \frac{\gamma M}{r c^2} \right).
$$

We see, that the formula (54) coincides the formula (50).

V. DISCUSSION

We have shown, that the GR predictions can be received, based on analogies between optical and mechanical phenomena. For this purpose it is enough to use only technique of rotations in extended space $G(1,4)$ and formula for the refraction index in the Schwarzchild metric. Any additional ideas and suppositions were not attracted. Actually obtained results are only first approximation in an evaluation of magnitude of gravitational effects.

These results can be improved, taking into account physical processes, which happen in extended space. So for example, calculation of magnitude of light deviation it was not taken into account, that the photon in a gravitational field gains a mass, and on it affected additional force of an attraction. However, it seems, that the magnitude of these additional effects is insignificant. This is showing an example of an evaluation of correction (32) to the frequency of a photon in the gravitational field.

However, the purpose of this work was not an evaluation of such corrections and arguing of possibilities of their real observation. Our purpose was to demonstrate that the ESM methods in the standard GR tasks give right results. In future we assume to use this results in the tasks of cosmology for description of dark energy and dark substance, which explanations have not received yet. Therefore that fact, that in well-known situations ESM works well. This gives hope that, and for other tasks model too will give right results.

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