MARRIAGE OF ELECTROMAGNETISM AND GRAVITY IN EXTENDED SPACE MODEL AND ASTROPHYSICAL PHENOMENA

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Abstract

The generalization of Einstein’s special theory of relativity (SRT) is proposed. In this model the possibility of unification of scalar gravity and electromagnetism into a single unified field is considered. Formally, the generalization of the SRT is that instead of (1+3)-dimensional Minkowski space the (1+4)-dimensional extension G is considered. As a fifth additional coordinate the interval $S$ is used. This value is saved under the usual Lorentz transformations in Minkowski space $M$, but it changes when the transformations in the extended space $G$ are used. We call this model the extended space model (ESM). From a physical point of view our expansion means that processes in which the rest mass of the particles changes are acceptable now. If the rest mass of a particle does not change and the physical quantities do not depend on an additional variable $S$, then the electromagnetic and gravitational fields exist independently of each other. But if the rest mass is variable and there is a dependence on $S$, then these two fields are combined into a single unified field. In the extended space model a photon can have a nonzero mass and this mass can be either positive or negative. The gravitational effects such as the speed of escape, gravitational red shift and deflection of light can be analyzed in the frame of the extended space model. In this model all these gravitational effects can be found algebraically by the rotations in the (1+4) dimensional space. Now it becomes possible to predict some future results of visible size of supermassive objects in our Universe due to new stage of experimental astronomy development in the RadioAstron Project and analyze phenomena is an explosion of the star V838 Mon.
**Keywords:** gravity, electromagnetism, interval, gravstar, multy-dimensional space, star V838 Mon.

1 Introduction

We consider a generalization of Einstein’s special theory of relativity (STR) in a 5-dimensional space, or more specifically in a (1+4)-dimensional space with a metric (+ - - - -). However, it is well known that the photon can be considered as a massless particle, and described by the plane wave only in an infinite empty space [1, 2].

But if a photon falls into the environment or in confined space, such as a resonator or waveguide, it acquires a nonzero mass, see [3, 4].

Under the particle mass $m$, we will understand its rest mass, which is a Lorentz scalar. No other masses will not appear in this work. Here we follow the recommendations of [5]. Similarly, we can consider the process of changing the mass of other particles, such as electrons, assuming that it depends on external conditions and influences.

Thus, it seems natural to expand the space of parameters characterizing particle, taking into account the fact that the interaction of its mass can vary. We call it the extended space.

2 The structure of the extended space

Such particle having a mass $m$, corresponds to a hyperboloid in Minkowski space, in the limiting case this hyperboloid degenerates into a cone.

$$s^2 = (ct)^2 - x^2 - y^2 - z^2.$$

(1)

Since the change of the mass of a particle corresponds its transition from one hyperboloid to the other, i.e. change of the corresponding interval, it seems natural to choose interval $s$ as an additional fifth coordinate. Thus, we will work in a space with coordinates $(t, x, y, z, s)$ and metric (+ - - - -). The objects under consideration are located on a cone

$$(ct)^2 - x^2 - y^2 - z^2 - s^2 = 0.$$

(2)

We denote this space as $G(1, 4)$. The Minkowski $M(1, 3)$ space is a subspace of $G(1, 4)$. An interval in the Minkowski $M(1, 3)$ space plays role of
the fifth coordinate in the $G(1,4)$ space. We designate this coordinate by the letter $S$. The other coordinates are designated as $T,X,Y,Z$. One of the characteristic features of this Extended Space Model (ESM) is that the particle’s rest mass $m_0$ is a variable quantity and a photon, moving in a medium with refraction index $n > 1$, acquires a nonzero mass. This mass can be both positive and negative.

The usual $(1+2)$-dimensional cones and hyperboloids occur as sections of the surface (2) by hyperplanes $s = s_0$. In the space $G(1,4)$ one can constructed in usual way the objects that have different tensor nature and transform appropriately under linear transformations of the $G(1,4)$ space [6].

In Minkowski space $M(1,3)$ a 4-vector of energy and momentum

$$\tilde{p} = \left( \frac{E}{c}, p_x, p_y, p_z \right)$$

(3)

is associated to each particle, [1].

In the extended space of $G(1,4)$, we completes its to 5-vector

$$\bar{p} = \left( \frac{E}{c}, p_x, p_y, p_z, mc \right).$$

(4)

For free particles, the components of the vector (4) satisfy the equation

$$E^2 = c^2 p_x^2 + c^2 p_y^2 + c^2 p_z^2 + m^2 c^4.$$

(5)

It is well-known relation of relativistic mechanics, which relates the energy, momentum and mass of a particle. Its geometric meaning is that the vector (4) is isotropic, i.e. its length in the space $G(1,4)$ is equal to zero. However, in contrary to the usual relativistic mechanics, we now suppose that the mass $m$ is also a variable, and it can vary at motion of a particle on the cones (2),(5). It should be understood so that the mass of the particle changes when it enters the region of the space that has a nonzero density of matter. Since in such areas the speed of light is reduced, they can be characterized by value $n$ - optical density. The parameter $n$ relates the speed of light in vacuum $c$ with the speed of light in a medium $v$.

$$v = \frac{c}{n}.$$  

(6)

A set of variables (4) forms a 5-pulse, its components are conserved, if the space $G(1,4)$ is invariant under the corresponding direction. In particular, its fifth component $p_4$, having sense of mass, does not change if the particle moves in the area with constant value $n$. 

3
3 The vectors of the free particles

In the usual relativistic mechanics and field theory the mass of a particle is constant, and for particles with zero masses and nonzero rest masses different methods of description are used. The particles with nonzero rest masses are characterized by their mass $m$ and speed $\vec{v}$. The particles with zero mass (photons) are characterized by frequency $\omega$ and wavelength $\lambda$. These $\omega$ and $\lambda$ are connected with energy $E$ and momentum $\vec{p}$ as follows

$$E = h\omega, \quad \vec{p} = \frac{2\pi h}{\lambda} \vec{k}. \quad (7)$$

The 4-vector

$$\vec{p} = \left( \frac{E}{c}, \vec{p} \right) = \left( \frac{mc}{\sqrt{1 - \beta^2}}, \frac{m\vec{v}}{\sqrt{1 - \beta^2}} \right), \quad (8)$$

$$\beta^2 = \frac{v^2}{c^2}.$$ 

corresponds to a particle with nonzero rest mass.

The 4-vector

$$\vec{p} = \left( \frac{h\omega}{c}, \frac{2\pi h}{\lambda} \vec{k} \right) = \left( \frac{h\omega}{c}, \frac{h\omega}{c} \vec{k} \right). \quad (9)$$

corresponds to a particle with zero mass.

In the frame of our approach, there is no difference between massive and massless particles, and therefore one can establish a connection between these two methods of description. This can be done using the relation (7) and the hypothesis of de Broglie, according to which these relations hold for the massive particles. Now, substituting (7) in (4), we obtain the relation between the mass $m$, frequency $\omega$ and wavelength $\lambda$

$$\omega^2 = \left( \frac{2\pi c}{\lambda} \right)^2 + \frac{m^2 c^4}{\hbar^2}. \quad (10)$$

$$\omega = \frac{mc^2}{\hbar \sqrt{1 - \beta^2}}, \quad \lambda = \frac{2\pi \hbar}{mv \sqrt{1 - \beta^2}}. \quad (11)$$
It follows that if \( v \to 0 \) \( \lambda \to \infty \), but \( \omega \to \omega_0 \neq 0 \). Here \( \omega_0 \) determines the energy of a particle at rest.

Now we construct 5-vectors from 4-vectors (8, 9). We suppose that a 5-vector

\[
\vec{p} = (mc, 0, mc)
\]  

(12)
corresponds to a stationary particle of mass \( m \).

The 5-vector of a particle, which moves with velocity \( \vec{v} \), can be obtained by transformation to the moving coordinate system. Then the vector (12) takes the form

\[
\vec{p} = \left( \frac{mc}{\sqrt{1 - \beta^2}}, \frac{m\vec{v}}{\sqrt{1 - \beta^2}}, mc \right).
\]  

(13)

Similarly the 4-vector (9) transforms into 5-vector

\[
\vec{p} = \left( \frac{h\omega}{c}, \frac{2\pi \hbar}{\lambda} \vec{k}, 0 \right).
\]  

(14)

At the transition to a moving coordinate system the vector (14) does not change its form, only the frequency \( \omega \) changes its value.

\[
\omega \to \omega' = \frac{\omega}{\sqrt{1 - \beta^2}}.
\]  

(15)

Thus, in empty space in a stationary reference frame there are two fundamentally different object with zero and nonzero masses, which in the space of \( G(1, 4) \) correspond to the 5-vectors

\[
\left( \frac{h\omega}{c}, \frac{h\omega}{c}, 0 \right)
\]  

(16)

and

\[
(\ mc, \ 0, \ mc).
\]  

(17)

For simplicity, we write the vectors (16), (17) in (1+2)-dimensional space. The vector (16) describes a photon with zero mass, the energy \( h\omega \), and
the velocity \( c \). The vector (17) describes a stationary particle of mass \( m \). The photon has a momentum \( p = \frac{\hbar \omega}{c} \), a massive particle has a momentum equal to zero. In the 5-dimensional space, these two vectors are isotropic, in Minkowski space only the vector (16) is isotropic.

The length of the vector \((x_0, x_1, x_2, x_3, x_4)\) is equal to

\[
l^2 = x_0^2 - x_1^2 - x_2^2 - x_3^2 - x_4^2
\]

If we restrict ourselves to Lorentz transformations in Minkowski space it is impossible to transform an isotropic vector into anisotropic one and vice versa. In other words in frame of the SRT photon can not acquire mass, and a massive particle can not be a photon. But in the extended space \( G(1, 4) \) a photon and a massive particle can be related to each other by a simple rotation.

As it was already mentioned the parameter \( n \) connects the speed of light in vacuum with that in the medium: \( v = c/n \). Using it, one can parametrize the fifth coordinate in the \( G(1, 4) \) space. The value \( n = 1 \) corresponds to the empty Minkowski space \( M(1, 3) \) in which light moves at the velocity \( c \). The propagation of light in a medium with \( n \neq 1 \) is interpreted as an exit of a photon from the Minkowski space and its transition into another subspace of \( G(1, 4) \) space. This transition can be described as a rotation in the \( G(1, 4) \) space. All types of such rotations were studied in [7].

For hyperbolic rotation through the angle \( \theta \) in the \((TS)\) plane the photon 5-vector (16) with zero mass is transformed in the following manner [7]:

\[
\left( \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c}, 0 \right) \Rightarrow \left( \frac{\hbar \omega}{c} \cosh \theta, \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c} \sinh \theta \right) = \left( \frac{\hbar \omega}{c} n, \frac{\hbar \omega}{c}, \frac{\hbar \omega}{c} \sqrt{n^2 - 1} \right).
\]

As a result of this transformation a particle with mass

\[
m = \frac{\hbar \omega}{c^2} \sinh \theta = \frac{\hbar \omega}{c^2} \sqrt{n^2 - 1}
\]

arise. The velocity of this particle is defined by formula (6).
Under the same rotation the massive 5-vector \((17)\) is transformed as

\[
(mc, 0, , mc) \Rightarrow (mce^{\theta \pm}, 0, mce^{\theta \pm}) ; \quad (20)
\]

\[
e^{\theta \pm} = n \pm \sqrt{n^2 - 1}.
\]

Under such rotation a massive particle changes its mass

\[
m \rightarrow me^{\theta}, \quad 0 \leq \theta < \infty \quad (21)
\]

and energy but conserves its momentum.

Upon rotation through the angle \(\phi\) in the (XS) plane the photon vector is transformed in accordance to the law

\[
\left(\frac{\hbar \omega}{c}, \frac{\hbar \omega}{c}, 0, \right) \Rightarrow \left(\begin{array}{c}
\frac{\hbar \omega}{c} \cos \phi, \\
\frac{\hbar \omega}{c}, \\
\frac{\hbar \omega}{c} \sin \phi
\end{array}\right) = \\
\left(\begin{array}{c}
\frac{\hbar \omega}{c}, \\
\frac{\hbar \omega}{c} \sin \phi, \\
\frac{\hbar \omega}{c} \sin \beta \sqrt{n^2 - 1}
\end{array}\right).
\]

Given this, the photon acquires the mass

\[
m = \frac{\hbar \omega}{c^2} \sin \phi = \frac{\hbar \omega}{c^2 n}, \quad (23)
\]

and velocity

\[
v = c \cos \phi = \frac{c}{n}, \quad (24)
\]

The vector of a massive particle is transformed in accordance to the law

\[
(mc, 0, mc) \rightarrow (mc, -mc \sin \phi, mc \cos \phi) = \\
\left(mc, -\frac{mc}{n} \sqrt{n^2 - 1}, \frac{mc}{n}\right).
\]

In this transformation the energy of a particle is conserved but its mass and momentum change

\[
m \rightarrow m \cos \phi = \frac{m}{n}, \quad (26)
\]
\[ 0 \to -mc \sin \phi = -\frac{mc}{n\sqrt{n^2 - 1}}. \]  

(27)

The important fact is that the photon mass generated by transformations (18,22) can have either positive and negative sign. This immediately follows from the symmetry properties of \( G(1,4) \) space. As to the particles that initially had positive mass, after transformations (20,25) it remains positive.

4 Electrodynamics and gravitation in the extended space

The source of the electromagnetic field is a current. In the traditional formulation of the electromagnetic theory the current is described by a 4-vector in Minkowski space \( M(1,3) \) [1].

\[ \tilde{\rho} = (\rho, \vec{j}) = \left( \frac{\rho_0 c}{\sqrt{1 - \beta^2}}, \frac{\rho_0 \vec{v}}{\sqrt{1 - \beta^2}} \right), \]  

(28)

\[ \beta^2 = \frac{v^2}{c^2}, \quad \rho^2 = c^2 \rho_0^2. \]

Here \( \rho_0(t, x, y, z) \) - is an electric charge density in the point \( (t, x, y, z) \) in the space \( M(1,3) \), and \( (v_x(t, x, y, z), v_y(t, x, y, z), v_z(t, x, y, z) \) - is a local velocity of a charge density.

At the transition to the extended \( G(1,4) \) space it is necessary to change a (1+3)-current vector \( \tilde{\rho} \) by a (1+4)-vector \( \tilde{\rho} \). In accordance with the principles of the developed model, an additional coordinate of the vector \( \tilde{\rho} \) must be an isotropic (1+4)-vector. In addition, we want our model describes both the electromagnetic and gravitational field, so the fifth component of the current should be defined so that it be the source of the gravitational field.

We suppose that the source of a unit electromagnetic and gravitational field, is a particle which has both a mass and a charge. In this case, we assume that the mass may not have any charge, but the charge should always have a mass. In our model we assume that the charge is constant and does not change under transformations of the rotation group \( L(1,4) \) of the extended space \( G(1,4) \). And the rest mass, which is a scalar with respect to the Lorentz group, is a fifth component of the vector with respect to the group of \( L(1,4) \).

We want to construct a 5-dimensional current vector \( \tilde{\rho} \) as a generalization of 4-dimensional current vector \( \tilde{\rho} \). To do this one must add one component to it.
In the ordinary electrodynamics 4-dimensional current vector $\tilde{\rho}$ has the form (28). Its structure is similar to structure of the energy-momentum vector (8) of the particle, having a rest mass. The difference between them is that in the vector (28) instead of the rest mass $m_0$ there is a local density of charge $\rho_0$. In the extended space $G(1, 4)$ we consider the energy-momentum-mass vector (28) instead of the energy-momentum vector (8).

Thus, the 5-dimensional current vector, generating a unit electro-gravitational field, has the form

$$\bar{\rho} = (j_0, \vec{j}, j_4) = \left(\frac{emc}{\sqrt{1 - \beta^2}}, \frac{em\vec{v}}{\sqrt{1 - \beta^2}}, emc\right).$$

It is an isotropic vector

$$\bar{\rho}^2 = 0.$$

The continuity equation, as in the usual case, is expressed by the vanishing of the 5-divergence of the 5-current

$$\sum_{i=0}^{4} \frac{\partial j_i}{\partial x_i} = 0.$$  

(30)

If the charge is at rest the continuity equation takes the form

$$\frac{\partial m}{\partial t} + \frac{\partial m}{\partial x_4} = 0.$$  

(31)

Equation (31) can be interpreted as the variation of the rest mass of the particle by changing the properties of the environment.

In ordinary electrodynamics the law of conservation of charge follows from the continuity equation

$$\frac{\partial}{\partial t} \int j_0 dV = - \int \vec{j} d\vec{n}. $$  

(32)

There is an integral over the volume in the left side of this equation, and the right side - is the integral over the surface bounding this volume.

In electro-gravidynamics there is a law of conservation of the value, which is the product of the charge at the mass of a particle, which hold this charge. This law reads

$$\frac{\partial}{\partial t} \int j_0 dV = - \int \vec{j} d\vec{n} - \int \frac{\partial}{\partial x_4} j_4 dV.$$  

(33)
In this case, the change in the product of \( em \) of a charge at the mass inside a volume is defined as a stream of charged particles across the surface of the volume and change of masses of particles within the volume due to their dependence on the coordinate \( x_4 \).

The current \((29)\) generates the electro-gravitational field in the extended space of \( G(1, 4) \). The potentials of this field are determined by the equations \([7, 8]\).

\[
\Delta^{(5)} A_0 = -4\pi \rho, \tag{34}
\]

\[
\Delta^{(5)} \vec{A} = -\frac{4\pi}{c} \vec{j}, \tag{35}
\]

\[
\Delta^{(5)} A_s = -\frac{4\pi}{c} j_s. \tag{36}
\]

Here

\[
\Delta^{(5)} = \frac{\partial^2}{\partial s^2} + \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{c^2} \frac{\partial^2}{\partial t^2}. \tag{37}
\]

With the help of the potentials \((A_0, A_x, A_y, A_z, A_s)\) one can construct the tension tensor

\[
F_{ik} = \frac{\partial A_i}{\partial x_k} - \frac{\partial A_k}{\partial x_i}; \quad i, k = 0, 1, 2, 3, 4. \tag{38}
\]

\[
||F_{ik}|| = \begin{pmatrix}
0 & -E_x & -E_y & -E_z & -Q \\
E_x & 0 & -H_z & H_y & -G_x \\
E_y & H_z & 0 & -H_x & -G_y \\
E_z & -H_y & H_x & 0 & -G_z \\
Q & G_x & G_y & G_z & 0
\end{pmatrix} \tag{39}
\]

Here

\[
Q = F_{40} = \frac{\partial A_4}{\partial x_0} - \frac{\partial A_0}{\partial x_4} = \frac{\partial A_s}{c \partial t} - \frac{\partial \varphi}{\partial s}. \tag{40}
\]
Here is the equation satisfied by the intensity of \( F_{ik} \). We’ll call them the extended Maxwell system. The usual system of Maxwell equations consists of two pairs of equations, which have fundamentally different structures. They are usually well known as the first and second pair of Maxwell’s equations. Extended system of Maxwell’s equations also consists of two types of equations fundamentally different structure. We shall call them the equations of the first and second types.

The equations of the first type are formal consequence of the formula (38), which expresses the tension via potentials. It follows immediately from their form that for any three indices \((i, j, k)\) the relation

\[
\frac{\partial F_{ij}}{\partial x_k} + \frac{\partial F_{ki}}{\partial x_j} + \frac{\partial F_{jk}}{\partial x_i} = 0 \tag{42}
\]

is satisfied.

The validity of (42) can be verified by direct substitution of the expression (38) in the equation (42).

\[
\frac{\partial^2 A_i}{\partial x_k \partial x_j} - \frac{\partial^2 A_j}{\partial x_k \partial x_i} + \frac{\partial^2 A_k}{\partial x_j \partial x_i} - \frac{\partial^2 A_i}{\partial x_j \partial x_k} + \frac{\partial^2 A_j}{\partial x_i \partial x_k} - \frac{\partial^2 A_k}{\partial x_i \partial x_j} = 0.
\]

There are exist 10 such equations. Let us consider now the specific form of these equations, using the tension tensor (39).

If we restrict ourselves to the sets of indices taking values \((0,1,2,3)\), then corresponding 4 equation are simply the first pair of Maxwell’s equations

\[
div \vec{H} = 0, \quad \text{sim indices } (1,2,3). \tag{43}
\]

This is one equation. The three other equations which correspond to sets of indices \((0, 1, 2), (0, 1, 3), (0, 2, 3)\) form a unit vector equation

\[
rot \vec{E} + \frac{1}{c} \frac{\partial \vec{H}}{\partial t} = 0. \tag{44}
\]
Thus, the first pair of Maxwell’s equations retain its form. In the extended space \( G(1,4) \) another 6 equations are added to them. Three of them, that are corresponding to the sets (1, 2, 4) (1, 3, 4), (2, 3, 4), can be combined into one vector equation

\[
rot \vec{G} + \frac{\partial \vec{H}}{\partial s} = 0. \tag{45}
\]

The other three triples (0, 1, 4) (0, 2, 4) (0, 3, 4) give us the three remaining equations of the first type. They also can be merged into a single vector equation

\[
\frac{\partial \vec{E}}{\partial s} + \frac{1}{c} \frac{\partial \vec{G}}{\partial t} + \text{grad} Q = 0. \tag{46}
\]

Thus, the equation of the first type from the extended system of Maxwell’s equations in the space \( G(1,4) \) have the form (43)-(46). These 10 equations can be combined into three vector equations and one scalar equation. Note that the vector operators \( \text{div}, \ rot, \ \text{grad} \), that appear in these equations have the usual three-dimensional form.

Let’s turn now to construction of the Maxwell equations of the second type. These equations are follow from the equations for the potentials (34)-(36). However, it is necessary first to impose the Lorentz gauge condition, which must satisfy potential (33). In the space \( G(1,4) \) it has the form

\[
\frac{1}{c} \frac{\partial A_0}{\partial t} + \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} + \frac{\partial A_s}{\partial s} = 0. \tag{47}
\]

The second type of Maxwell’s equations from the extended system reads

\[
\sum_{k=0}^{4} \frac{\partial F_{ik}}{\partial x_k} = -\frac{4\pi}{c} j_i; \quad i = 0, 1, 2, 3, 4. \tag{48}
\]

Substituting the elements of the tension tensor \( \mathbf{T} \) into the equation (48) and taking into account the Lorentz gauge condition (47), one can obtain five vector equations.

\[
\text{div} \vec{E} + \frac{\partial Q}{\partial s} = 4\pi \rho, \quad (i = 0) \tag{49}
\]
\[ \text{rot}\vec{H} - \frac{\partial \vec{G}}{\partial s} - \frac{1}{c} \frac{\partial \vec{E}}{\partial t} = \frac{4\pi \gamma}{c} j, \quad (i = 1, 2, 3) \tag{50} \]

\[ \text{div}\vec{G} + \frac{1}{c} \frac{\partial Q}{\partial t} = 4\pi j_4, \quad (i = 4). \tag{51} \]

The tension tensor (39) contains, in addition to the components that are analogous to the usual electric and magnetic fields, some additional components that describe gravitational field. More precisely, in the case when the components of the 5-current (6) depend on the coordinate \(x_4\), all components of (39) describe a single electro-gravitational field. If the current does not depend on the coordinate \(x_4\), the system of equations (44), (46), (48), (51) splits into two systems. One of them is the system of Maxwell’s equations and the other is a Laplace equation for the scalar gravitational field.

Thus, according to our model, in an empty space the gravitational and electromagnetic fields exist as two different fields, but in the region where there are particles and fields they form a unit electromagnetic-gravitational field.

### 5 Refraction index of a gravitational field

Let’s now study a problem of refraction index of a gravitational field. Let there is a point mass, which gravitational field is described by the Schwarzschild solution. We assume, that the gravitational radius \(r_g\) is small and we will consider all effects at distance \(r > r_g\). In the literature there are considered two expressions for refraction index \(n\), appropriate to the Schwarzschild field. One of them, we shall name it \(n_1\), is used in papers of Okun’ [11, 12] and looks like

\[ n_1(r) = (g_{00})^{-1} = (1 - \frac{r_g}{r})^{-1} = 1 + \frac{2\gamma M}{rc^2}. \tag{52} \]

It can be found in the supposition, that in a constant gravitational field the frequency of a photon \(\omega\) remains constant, but the wavelength \(\lambda\) and speed \(v\) are varied. The other refraction index \(n_2\) one can get from the formula of an interval in a weak gravitational field [1].

\[ ds^2 = (c^2 + 2\varphi)dt^2 - d\vec{r}^2. \tag{53} \]
Here $\varphi$ is a potential of gravitational field. Supposing that $d\vec{r} = \vec{v}dt$ and $ds^2 = 0$, one can find a speed of photon in a gravitational field

$$v = c \left(1 + \frac{2\varphi}{c^2}\right)^{1/2} \approx c \left(1 + \frac{\varphi}{c^2}\right). \quad (54)$$

It is necessary here to take into account the fact that a potential of a gravitational field $\varphi$ is negative. For a point mass $M$ we have

$$\varphi(r) = -\frac{\gamma M}{r}. \quad (55)$$

Substituting the expression (55) in the formula (54), one gets

$$v \approx c \left(1 - \frac{\gamma M}{rc^2}\right). \quad (56)$$

Collins obtained the same formula in another way [13]. He considered a particle of mass $m_0$, located indefinitely far from a point source of a gravitational field of mass $M$. Such particle has an energy $E_0 = m_0c^2$. When moving on a distance $r$ from a source of a field, particles energy increases up to size

$$E = m_0c^2 + \frac{\gamma m_0 M}{r}.$$ 

Collins offered to interpret this change of energy as change of a rest mass in a gravitational field.

$$m = m_0 \left(1 + \frac{\gamma M}{rc^2}\right). \quad (57)$$

Then he used a conservation law of a momentum $mv = m_0v_0$ and received the law of change of speed in a gravitational field

$$v = v_0 \left(1 + \frac{\gamma M}{rc^2}\right)^{-1}. \quad (58)$$

Supposing, that this law is valid also for photons, we get the formula for change of photons speed in a gravitational field

$$v = c \left(1 + \frac{\gamma M}{rc^2}\right)^{-1} \approx c \left(1 - \frac{\gamma M}{rc^2}\right). \quad (59)$$
It is possible to interpret the formulas (56), (59) as hit of a photon in medium with a refraction index

\[ n_2(r) = 1 + \frac{\gamma M}{rc^2}. \quad (60) \]

In the case, when the speed of a particle \( v \) is comparable with the speed of light \( c \), it is necessary to take into account in the formula (57) relativistic correction to a rest-mass \( m \) and to record it as

\[ M = m_0 \left( 1 + \frac{\gamma M}{rc^2} + \frac{v^2}{2c^2} \right). \quad (61) \]

Appropriate refraction index will look like

\[ n' = 1 + \frac{\gamma M}{rc^2} + \frac{v^2}{2c^2}. \quad (62) \]

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 different rotations in extended space correspond to these situations.

6 Gravitational effects in ESM

1) Speed of escape. The 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

\[ v_2 = \sqrt{2gR} = \sqrt{\frac{2\gamma M}{R}}. \quad (63) \]

We will receive now formula (63) 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 (4). 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
Such motion is described by some rotation in expanded space $G(1, 4)$. The rotation angle express through refraction index $n$. Thus the massive particle at rest acquires speed

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

As to in this case we consider a motion of a massive body, so we assume natural to use the refraction index $n_2$. Assuming, that it is close to unit, i.e. that

$$1 >> \epsilon = \frac{\gamma M}{rc^2},$$

one can get, that

$$V \approx c\sqrt{2\epsilon}.$$ (65)

In case, when $r = R$ - is the radius of the Earth, the formula (65) coincides with the formula (63) 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, see [1]. However Okun’ offered to recognize that not frequency varies but wavelength of a photon varies, and just it named as red displacement [11, 12]. Under our judgment both cases are possible, but they correspond to different physical situations and are described by different rotation angles express through refraction index $n$. In the general theory of relativity the formula that describes change of light frequency is, [1]

$$\omega = \frac{\omega_0}{\sqrt{g_{00}}} \approx \omega_0 \left(1 + \frac{\gamma M}{rc^2}\right).$$ (66)

Here $\omega_0$ - is a frequency of a photon measured in universal time, it remains constant at propagation of a beam of light. And $\omega$ - is a 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 the same problem from the ESM point of view. Within the framework of our model the isotropic 5-vector (4) is compared to a photon located in empty space. Process of its movement to the point with refraction index \( n \), at which the change of frequency and energy happens, is described by a rotation in (TS) plane. At these rotations the photon vector are transformed as

\[
\frac{\hbar \omega}{c} (1, 1, 0) \rightarrow \frac{\hbar \omega}{c} (cosh \theta, 1, sinh \theta) = \frac{\hbar \omega}{c} (n, 1, \sqrt{n^2 - 1}) .
\]

One can see from here that the frequency \( \omega_0 \) of a photon in vacuum and its frequency \( \omega \) in a field, are connected by a ratio

\[
\omega = \omega_0 \cosh \theta = \omega_0 n .
\]

We assume, that at calculation of change of photon frequency it is necessary to use refraction index \( n_2 \), as to the index of refraction \( n_1 \) was found in the supposition, that this frequency does not vary. Substituting (60) in (68), we get the formula

\[
\omega = \omega_0 n_2 = \omega_0 \left(1 + \frac{\gamma M}{r c^2}\right) ,
\]

which coincides with the formula (66). Thus in extended space model for red shift is received the same expression, as in general theory of relativity.

In papers [11, 12] Okun’ has offered to consider the 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

\[
g^{00} = \left(1 - \frac{r_g}{r}\right)^{-1}, \quad g^{rr} = \left(1 - \frac{r_g}{r}\right),
\]

\[
r_g = \frac{2\gamma M}{c^2}.
\]
Assuming, that \( p_0 = h\omega = \text{const} \), Okun’ has received for relation of a momentum \( p_r \) from a radius \( r \) the expression

\[
p_r (r) = \frac{h\omega}{c}(1 - \frac{rg}{r})^{-1} = p_r(\infty)n_1,
\]

(72)

Here \( p_r(\infty) \) - is a 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 get the expression

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

(73)

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

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

(74)

Let’s look now at transformation (67) 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 (XS) of the spaces G(1,4). As the frequency does not vary, we take the refraction index \( n_1 \). At such rotation the speed of a photon varies according to the formula

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

(75)

This formula coincides with the formula (6) for transformation of speed. Being repelled from it is possible to receive the formula (73), assigning change of a wavelength of a photon, when photon hit in a gravitational field.

From a point of view of our model it is necessary to consider the formula (67) 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 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 [14]. The energy change which appropriated to such frequency shift, is equal

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

(76)
According to the formula (6) in the case of rotation in plane (TS) the photon gains a mass

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

(77)

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

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

(78)

Near to a surface of the Earth refraction index of gravitational field is defined by the formula (60). Taking into consideration an inequality (64), one can get an evaluation

\[ \delta E = mgH = \left( \frac{\hbar \omega}{c^2} \right) gH \sqrt{n^2 - 1} \approx \left( \frac{\hbar \omega}{c^2} \right) gH \sqrt{2gM R c^2} = \left( \frac{\hbar \omega}{c^2} \right) gH \sqrt{2gR c^2} \approx \left( \frac{\hbar \omega}{c^2} \right) gH (2.5 \cdot 10^{-5}). \]  

(79)

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 [15]. Such experiments give satisfactory agreement with GR predictions. These experiments also were analyzed in [16]. 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 GRT. This result can be obtained from the fact that the photon time delay \( \Delta t \) is calculated from only from the photon velocity \( v(t) \) [11, 12]. Let’s imagine that we locate
Sun. In this case we have

$$\Delta t = 2 \left( \int_{R_s}^{r_e} \frac{dr}{v(r)} - \int_{R_s}^{r_e} \frac{dr}{c} \right).$$

(80)

Here $R_s$ - is the radius of Sun, $r_g$ - is a gravitational radius of Sun, and $r_e$ - is a distance from Earth up to Sun. The 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 (80), we obtain

$$\Delta t = 2\frac{r_g}{c} \ln \frac{r_e}{R_s}.$$  \hspace{1cm} (81)

The formula (81) coincides with expression for magnitude of radar echo delay obtained in works [12, 16].

4) Deviation angle of a light beam.

In general theory of relativity the magnitude of deviation angle $\delta \psi$ of a light beam from a rectilinear trajectory in the 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 [1]. In this case one finds

$$\delta \psi = \frac{\gamma M}{Rc^2}.$$  \hspace{1cm} (82)

Here $M$ - is a mass of a body, and $R$ - is a 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 $x$ from it. It is supposed, that

$$h << R_s < r = \sqrt{x^2 + R^2}.$$

In the case of passing by these rays of a linear segment of length $dx$ the residual of optical paths will be

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

$$dx \left( 1 - \frac{r_g}{r} \right) - dx \left( 1 - \frac{r_g}{r + h \cos \varphi} \right) \approx \frac{r_g h \cos \varphi}{r^2} dx.$$  \hspace{1cm} (83)
To such difference of optical paths there corresponds an angle of a wave front deviation

$$\delta \varphi \approx \frac{\delta x}{\hbar} = \frac{r_g \cos \varphi}{r^2} dx = \frac{r_g R_s}{r^3} dx = \frac{r_g R_s}{(x^2 + R_s^2)^{3/2}} dx.$$  (84)

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

$$\varphi = r_g R_s \int_{-\infty}^{\infty} \frac{dx}{(x^2 + R_s^2)^{3/2}} = 2 \frac{r_g}{R_s} = 2 \frac{\gamma M}{R_s c^2}. \quad (85)$$

Expression (84) yields half the angle (82). This expression is obtained in the geometrical-optics approximation ignoring the fact that according to the ESM the photon must acquire a mass in the gravitational field. For this effect we now estimate the second half caused by the fact that in the gravitational field the photon acquires a nonzero mass. In the case under discussion the value of this mass is of no importance, and we denote simply as $m_f$. We analyze the motion of a particle of mass $m_f$ assuming this particle to move with impact parameter $R$ to the center of the gravitational field produced by the mass $M$. Let the motion of a particle in the (XY) plane be described by the Newton equation

$$m_f \frac{d^2 y}{dt^2} = -\gamma \frac{M m_f y}{r^2 \frac{r}{r}}. \quad (86)$$

Here $r^2 = x^2 + y^2$.

The photon mass $m_f$ is supposed to be constant. For this reason we can exclude it from equation (86). We assume that the motion of the photon proceeds basically along the $X$ axis, and the variable $y$ varies only slightly remaining close to the value of the impact parameter $R$. We also consider the photon velocity to remain constant all the time and to be equal to the velocity $c$ of light in vacuum. Therefore, using the relationship

$$y \approx R, \quad x = ct, \quad (87)$$

we can transform equation (86) to the form

$$\frac{d^2 y}{dx^2} = \gamma \frac{M R}{r^3}. \quad (88)$$
After the first integration, we arrive at
\[ \frac{dy}{dx} = \frac{\gamma M}{c^2 R \sqrt{x^2 + y^2}}. \]  (89)

Using this equation we can calculate the deflection angle
\[ \theta \approx \left. \frac{dy}{dx} \right|_{-\infty} - \left. \frac{dy}{dx} \right|_{\infty} = 2 \frac{\gamma M}{c^2 R}. \]  (90)

When the impact parameter \( R \) equals the Sun radius \( R_s \), the angle \( \theta \) coincides with the angle \( \varphi \) given by the formula (85). In the ESM these two effects are summed up to yield the total deflection angle
\[ \theta + \varphi = 4 \frac{\gamma M}{c^2 R}. \]  (91)

The result (91) coincides with formula (82).

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 particle becomes nonclosed, and after of each rotation it the perihelion recessed 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
\[ F(r) = -\frac{\gamma M m}{r^2 \sqrt{1 - R_g/r - v^2/c^2}}. \]  (92)

Here \( R_g \) is the gravitational radius corresponding to the mass \( M \), and \( v \) is the orbital velocity of a particle of mass \( m \). The velocity of Mercury orbital motion around the Sun is approximately equal to 48 km/s, which results in the relativistic correction \( v^2/c^2 \approx 5 \times 10^{-8} \). The gravitational correction also attains \( R_g/r \approx 5 \times 10^{-8} \) and is very close to the relativistic one. One can assume that the particle mass \( m \) in formula (92) depends on both the distance and velocity. However as both these corrections are small one can write the total transformation of mass \( m \) in the form
\[ m \to m \left( 1 + \frac{\gamma M}{rc^2} + \frac{1}{2} \frac{v^2}{c^2} \right). \]  (93)
The calculation using the expression for the force (92) with allowance for approximation (93) yields the Mercury perigee shift to the observed one.

Let’s now analyze this problem from the standpoint of ESM. We deal with a nonzero mass particle placed into the gravitational field. Since one cannot already ignore the relativistic corrections, we will use the refraction index in the form (62). In this case the particle gets from a domain with a refraction index \( n = 1 \) to a domain with refraction index \( n' \) because of the variation of the force acting on it, i.e. because of a change of its energy. Therefore the (TS) rotation in \( G(1, 4) \) space should be used. In the case of this rotation the massive vector is transformed in accordance with formula (20) and a massive particle changes its mass obeying the formula (21). Under such transformation particles of masses \( m_+ \) and \( m_- \) can arise from mass \( m \).

\[
\begin{align*}
    m_+ &= m e^{\theta_+} = m(n + \sqrt{n^2 - 1}), \\
    m_- &= m e^{\theta_-} = m(n - \sqrt{n^2 - 1}).
\end{align*}
\]

We assume that a macroscopic massive body has an equal number of particles transformed according to laws (94). We will use for this situation the average transformation law

\[
m \rightarrow mn_2' = m \left(1 + \frac{\gamma M}{rc^2} + \frac{1}{2} \frac{v^2}{c^2}\right),
\]

As one can see formulas (93) and (95) coincide.

### 7 Radioastron mission - visible size of bubble objects

In recent years new phenomena which go beyond the traditional GRT-based concepts concerning the structure of Universe, have been discovered by astronomers. The essence of these phenomena is basically as follows:

1) The bulk of the Universe mass (more than 90%) is dark matter and hidden energy which is associated with the cosmic vacuum. 2) This dark matter does not emit electromagnetic radiation and does not interact with it, but shows gravitational properties. 3) The cosmic vacuum possesses negative pressure or, in other words shows antigravitational properties, which
determine the current dynamics of Universe expansion. 4) Usual massive objects are surrounded by dark-matter halo.

The ESM gives us an approach for the explanation of these phenomena. As was already shown the motion in the additional fifth dimension corresponds to change of the particle rest mass. When the photon gets into the external field, it acquires a nonzero mass which can be either positive or negative. We suppose that the inertia of such mass is always positive, and it is only its gravitational properties that can have different signs. In a pair of photons born in an external field one has a positive and the other a negative mass. According to ESM the dark matter consists of massive photons. Positive-mass photons are concentrated around massive stars and black holes and form their halos. Negative-mass photons are thrown away into the free cosmic space where they create an antigravitating vacuum with negative pressure. Hence, in our opinion, the dark matter mostly consists of positive-mass photons and the dark energy is generated by negative-mass photons. Different ways of assigning a nonzero mass to a photon are discussed in review [4]. The possibility of the existence of bodies with a negative mass was discussed in [13]. Attention has recently been drawn by a new gravitational model, the so-called gravstar, or gravitational condensate star [19]. It has been proposed as an alternative to black holes. These objects correspond to the solutions of Einstein equations which outside a region occupied by masses coincides with the Schwarzschild solution. Inside it there is another nonsingular solution, and so the metric as a whole appears to be nonsingular. The gravstar structure is similar to that of a bubble. A bubble has a rigid dense shell which is stressed because of a liquid substance pressing out from inside. This particular model is now typically used to explain the nature of some observed objects. It is shown that in ESM model formation of bubble gravitational structures is possible. In the frame of ESM one can obtain the follow physical picture. Bubble gravitational objects have a halo formed by dark matter generated by photons with a positive mass. Now it becomes possible to predict some future results of visible size of supermassive objects in our Universe due to new stage of experimental astronomy development in the RadioAstron Project [20, 21, 22]. As to in RadioAstron Project has to reached unprecedented angular resolution equal 0.00001” it is becomes possible to distinguish real size of such objects active galactic nuclei to investigate the size of supermassive objects applying for black hole role and to obtain direct results of comparison event horizon with its radius. In the case when the visible radius of supermassive object will not exceed the gravitational ra-
dius we will agree that this object is real black hole. In the case when visible radius will be in 2 to 3 times larger than gravitational radius appropriated to the mass of supermassive object - we will discuss the nature of such objects with taking into account that one of the possible answers is the gravastar.

8 V838 Monocerotis explosive outburst - local Big Bang or light echo?

The ESM can be applied to analysis of new phenomenon taking place in the Universe. They did not have until now any generally accepted physical explanation. One of these mysterious phenomena is an explosion of the star V838 Mon. In 2002, the previously unknown variable star V838 Monocerotis brightened suddenly by a factor of about $10^4$. Unlike a supernova or nova, V838 Mon did not explosively eject its outer layers; rather, it simply expanded to become a cool supergiant with a moderate-velocity stellar wind. Investigation of this phenomenon show, that hen combined with the high luminosity and unusual outburst behavior, these characteristics indicate that V838 Mon represents a hitherto unknown type of stellar outburst, for which we have no completely satisfactory physical explanation [23]. The morphing sequence of six images taken by Hubble’s Advanced Camera of V838 explosion could be found at [24]. V838 image evolution was attributed not to a cloud expanding (as are normal supernovas) but light echoing (hitting different parts) of an interstellar cloud. A set of mechanism were proposed to explain outburst see reference in [25]. There is some discussion with the nature of light echo and source of light echo materials as to due to estimation [26] mass light echo materials is about 90-150 mass of the Sun. In the frame of ESM one can consider a possibility to explain V838 explosive outburst [9, 10]. We could interpret this phenomenon as local Big Bang. Thus we try to consider V838 evolution in ESM formalism as a new space local birth. In our (4+1)-dimensional model V838 expansion could be explained as evolution of high-dencity complex field consisting from 4 fields - scalar field Q, gravitational field G, electic feild E and magnetic field H. We also discuss the nature of origin SiO maser emission from the direction of V838 [25]. In the framework of our ESM model we also explain the absence of large molecular lines shift in the spectrum of CO and AlO [25, 26].
9 Conclusion

In given work the generalization of Einstein’s Special theory of relativity is proposed. It is the (4+1)-dimensional Extended space model. In this model gravity and electromagnetism are unified into a single field. The gravitational effects such as the speed of escape, gravitational red shift and deflection of light can be found algebraically by the rotations in the (1+4) dimensional space. The dark matter and hidden energy get natural interpretation in the frame of this model. Thus, in ESM frameworks there is a mechanism, according to which in a neighborhood of massive gravitational objects the halo consisting of photons with positive masses can be formed. These halos we associate with a dark matter. The photons with negative masses are concentrated far from massive objects. These photons will create areas of a dark energy. Such areas are characterized by negative pressure and exhibits properties of antigravitation.

We also consider a possibility to explain V838 explosive outburst with its help. We suppose that this phenomenon can be interpreted as a local Big Bang. In this case we see the movement of the space itself, and the rate of its expansion is seen as the rate of expansion of stars shell. The observed rate of expansion may exceed the speed of light.

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