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S.S. Gershtein, A.A. Logunov, M.A. Mestvirishvili

# ON ONE FUNDAMENTAL PROPERTY OF GRAVITATIONAL FIELD IN THE FIELD THEORY

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**Abstract**

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It is shown that the universal property of gravitational field to slow down the rate of time leads in the field theory to a fundamental property — generation of effective forces of repulsion.

**Аннотация**

Герштейн С.С., Логунов А.А., Мествиришвили М.А. Об одном фундаментальном свойстве гравитационного поля в полевой теории: Препринт ИФВЭ 2004–50. – Протвино, 2004. – 5 с., библиогр.: 4.

В статье показано, как универсальное свойство гравитационного поля замедлять ход времени приводит в полевой теории к фундаментальному свойству: создавать эффективные силы отталкивания.

There is a common belief that the gravitational field provides only forces of attraction. It is seen, for example, from the fact that the physical velocity of a test body increases when it is approaching the gravitating body. However this is not quite so for strong fields. Let us consider this later. When A. Einstein had connected gravitational field with the Riemannian space metric tensor in 1912 it was found that such a field was slowing down the rate of time for a physical process. This slowing down can be demonstrated, in particular, by the example of Schwarzschild solution, if we compare the rate of time in the gravitational field with the rate of time for a distant observer. Nevertheless in general case there is only Riemannian space metric tensor in General Relativity and there are not any indication of the inertial time of Minkowski space. Just for this reason the universal property of gravitational field to slow down the time rate in comparison to the inertial time could not be further developed in General Relativity. The situation is rather opposite in the Relativistic Theory of Gravitation (RTG) as it is a field theory. In this approach the gravitational field is treated as a physical field of Faraday-Maxwell type which is developing in Minkowski space in line with all the other physical fields.

The source of universal gravitational field is the total conserved energy-momentum tensor of all matter including the gravitational field. Therefore the gravitational field is a tensor field with spins 2 and 0. Just this fact leads to **geometrization**: the effective Riemannian space arises but with trivial topology. This leads to the following situation: the motion of a test body in Minkowski space under the action of gravitational field is equivalent to the motion of this body in the effective Riemannian space created by this gravitational field. The arising of the effective Riemannian space in the field theory side by side with preserving the role of Minkowski space as the fundamental space gives a special meaning to the property of the gravitational field to slow down the time rate. Just in this case it is only possible to speak about the slowing of time in full, by comparing the time rate in the gravitational field with the time rate in inertial frame of reference of Minkowski space in the absence of gravitation. And all this is realized in the RTG because the metric tensor of Minkowski space enters into the full system of its equations. But this general property of the gravitational field to slow down the time rate leads in the field theory to a remarkable conclusion: **the slowing down of the physical process time rate in a strong field generates effective field forces of the gravitational nature. These effective forces in gravitation occur to be repulsive**.

To demonstrate that a change of the time rate leads to arising of a force let us consider Newton equation

$$\frac{d^2x}{dt^2} = F\,.$$

If we formally transform this equation in order to change the inertial time $t$ for time $\tau$ according to the rule

$$d\tau = U(t)dt\,,$$

then we easily get

$$\frac{d^2x}{d\tau^2} = \frac{1}{U^2}\Big\{F - \frac{dx}{dt}\frac{d}{dt}\ln U\Big\}\,.$$

It is seen from here that a change in time rate determined by function $U$ leads to arising of the effective force. But all this is of purely formal character because there are no any physical reason in this case that could change the time rate. But just this formal example demonstrates that when a process of slowing down time takes place in nature it inevitably generates effective field forces, and therefore it is necessary to account for them in the theory as something rather new and surprising.

And just here we are to turn to gravitation. The physical gravitational field changes both the time rate and parameters of spatial quantities in comparison to their values given in inertial system of Minkowski space when gravitation is absent. Just for this reason all this should be taken into account in the gravitational field equations. In the RTG metric tensor of Minkowski space appears unambiguously in these equations due to graviton mass introduced into them. Just this tensor provides the opportunity to account for effective field forces created by change of the time rate under action of the gravitational field. Here the graviton mass realizes a correspondence of the effective Riemannian space to the basic Minkowski space. Though the graviton mass is rather small nevertheless the influence of mass term becomes decisive because of great slowing down of the time rate under the action of gravitational field.

The complete system of RTG equations can be displayed as follows [1, 2]:

$$\Big(R^{\mu\nu} - \frac{1}{2}g^{\mu\nu}R\Big) + \frac{m_g^2}{2}\Big[g^{\mu\nu} + \Big(g^{\mu\alpha}g^{\nu\beta} - \frac{1}{2}g^{\mu\nu}g^{\alpha\beta}\Big)\gamma_{\alpha\beta}\Big] = 8\pi G T^{\mu\nu}\,, \tag{1}$$

$$D_\nu \tilde{g}^{\nu\mu} = 0\,. \tag{2}$$

Here $D_\nu$ is the covariant derivative in Minkowski space, $\gamma_{\alpha\beta}$ — metric tensor of Minkowski space, $g_{\alpha\beta}$ — metric tensor of the effective Riemannian space, $m_g$ — graviton mass. This system of equations is generally covariant under arbitrary coordinate transformations and form-invariant under Lorentz transformations.

Now let us demonstrate by examples of the collapse and evolution of the homogeneous isotropic Universe how effective field repulsive forces are developed due to slowing down of the time rate under action of the gravitational field. Consider the static spherically symmetric field

$$ds^2 = U(r)dt^2 - V(r)dr^2 - W^2(r)(d\Theta^2 + \sin^2\Theta\, d\phi^2)\,, \tag{3}$$

$$d\sigma^2 = dt^2 - dr^2 - r^2(d\Theta^2 + \sin^2\Theta\, d\phi^2)\,. \tag{4}$$

Here function $U(r)$ determines slowing down of the time rate in comparison to inertial time $t$.

Strong slowing down of the time rate takes place when this function is small enough in comparison to unity. Eqs. (1) take the following form for this problem defined by (3) and (4):

$$
\begin{aligned}
L_1 &= 8\pi G\rho - \frac{1}{2}m_g^2\Big[1 + \frac{1}{2}\Big(\frac{1}{U} - \frac{1}{V}\Big) - \frac{r^2}{W^2}\Big], \\
L_2 &= -8\pi Gp - \frac{1}{2}m_g^2\Big[1 - \frac{1}{2}\Big(\frac{1}{U} - \frac{1}{V}\Big) - \frac{r^2}{W^2}\Big], \\
L_3 &= -8\pi Gp - \tfrac{1}{2}m_g^2\Big[1 - \frac{1}{2}\Big(\frac{1}{U} + \frac{1}{V}\Big)\Big].
\end{aligned} \tag{5}
$$

If we put the graviton mass $m_g$ equal to zero, then system of equations (5) will coincide with the Hilbert-Einstein system of equations for problem given by Eqs. (3) and (4). In this case it will have the celebrated Schwarzschild solution, when functions $U$, $V$ and $W$ given as follows

$$
U = \frac{r - GM}{r + GM}, \quad V = \frac{r + GM}{r - GM}, \quad W = (r + GM)\,. \tag{6}
$$

It could be seen from here, in particular, that strong slowing down of the time rate in comparison to inertial time $t$ takes place in the region where $r$ is close to $GM$. But due to smallness of $U$ the terms standing in r.h.s. of Eq. (5) and having $U$ in their denominator will be dominate. Just this fact leads, after careful analysis [1–3] accounting for the graviton mass, to new expressions for functions $U$ and $V$ which are rather different from (6):

$$
U = \Big(\frac{GMm_g}{\hbar c}\Big)^2, \quad V = \frac{1}{2}\frac{W}{W - 2GM}\,. \tag{7}
$$

This provides the stopping of test body motion creating a turning point where velocity $dW/ds = 0$

$$
\frac{dW}{ds} = -\frac{\hbar c^2}{m_g GM}\Big[\frac{W}{GM}\Big(1 - \frac{2GM}{c^2 W}\Big)\Big]^{1/2}. \tag{8}
$$

The acceleration at this turning point is as follows

$$
\frac{d^2W}{ds^2} = \frac{1}{2GM}\Big(\frac{\hbar c^2}{m_g GM}\Big)^2, \tag{9}
$$

it is positive and it corresponds to a repulsive force. Just for this reason Schwarzschild singularity and therefore also the possibility of "black holes" formation is excluded.

Another example, demonstrating appearance of new effective field forces due to slowing down of the time rate is the evolution of homogeneous isotropic Universe. In this case we obtain, on the base of Eq. (2), the flat Universe solution with only Euclidean 3-dimensional geometry, i.e.

$$
\begin{aligned}
ds^2 &= d\tau^2 - \beta^4 a^2(dr^2 + r^2 d\Theta^2 + r^2\sin^2\Theta\, d\phi^2)\,, \\
d\sigma^2 &= \frac{1}{a^6}d\tau^2 - dr^2 - r^2 d\Theta^2 - r^2\sin^2\Theta\, d\phi^2\,.
\end{aligned} \tag{10}
$$

Here $\beta^4$ is a constant determined by the integral of motion. The proper time $d\tau$ is related to inertial time $dt$ by the following formula

$$
d\tau = a^3 dt. \tag{11}
$$

Eqs. (1) can be reduced, on the base of Eqs. (10), to the following system of equations for scale factor $a(\tau)$ [1, 2, 4]:

$$\left(\frac{1}{a}\frac{da}{d\tau}\right)^2 = \frac{8\pi G}{3}\rho(\tau) - \frac{1}{12}m_g^2\left(2 - \frac{3}{\beta^4 a^2} + \frac{1}{a^6}\right), \tag{12}$$

$$\frac{1}{a}\frac{d^2a}{d\tau^2} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) - \frac{1}{6}m_g^2\left(1 - \frac{1}{a^6}\right), \tag{13}$$

here we assume $\hbar = c = 1$. The scale factor $a(\tau)$ determines, through Eq. (11), the slowing down of the time rate produced by the action of gravitational field. But just this factor, standing in r.h.s. of Eq. (12) stops the process of Universe contraction when strong slowing down of the time rate. Then the minimal value of $a$ is as follows

$$a_{\min} = \left[\left(\frac{m_g c^2}{\hbar}\right)^2 \frac{1}{32\pi G\rho_{\max}}\right]^{1/6},$$

so the cosmological singularity is removed. From the other side, the repulsive force, created due to the slowing down of time rate, provides accelerated expansion of the Universe as follows from Eq. (13).

At the point of stopping the contraction acceleration is given as follows

$$\left.\frac{1}{a}\frac{d^2a}{d\tau^2}\right|_{\tau=0} = \frac{8\pi G}{3}\rho_{\max}\,.$$

Just this was “the impulse” to begin the Universe expansion. So, the field ideas of the gravitational field as a physical one give us the opportunity **to discover a fundamental property of the gravitational field — to create effective repulsive forces in strong fields due to slowing down the time rate**. There are no such forces in General Relativity. An interesting pattern arises: in RTG the gravitational field, developing itself through attraction forces and collecting matter, then enters a stage when, under the action of this strong field, the slowing down of time rate in comparison to the inertial time is starting, and this inevitably leads to creation of effective repulsive field forces which stop the process of matter contraction under attraction forces, providing later a process of expansion. We see that a special mechanism of self-regulation is supplied to the gravitational field in the field theory. Just this realizes stopping of the massive bodies collapse and removes the cosmological singularity, providing cyclic development of the Universe.

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ГНЦ РФ Институт физики высоких энергий
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