FIELD TRANSFORMATION IN THE EXTENDED SPACE MODEL:
PREDICTION AND EXPERIMENTAL TEST

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A run of preliminary experiments was carried out to check the prediction of possible gravitational field generation process arising by stopping of charged massive particles in a substance predicted by the recently developed Extended Space Model (ESM) [1, 3].

ESM is a model of the extended (1+4)-dimensional space $G(T; \vec{X}, S)$ with the interval $S$ as the fifth coordinate. Certainly, these five coordinates satisfy the relation $(ct)^2 - x^2 - y^2 - z^2 - s^2 = 0$. In addition to the Lorentz transformations $(T; \vec{X})$ in the (1+3)-dimensional Minkowski space, in ESM there exist two other transformations in the planes $(T; S)$ and $(\vec{X}; S)$. They convert massive particles into massless ones and vice versa.

We also considered the energy-momentum-mass (1+4)D space $G'(E; \vec{P}, M)$ which is conjugated to the time-coordinates-interval $(t; x, y, z, s)$ (1+4)D space, and thus a mass $m$ in 5D space $G'(E; \vec{P}, M)$ corresponds to the interval $s$ in 5D space $G(T; \vec{X}, S)$.

The coordinates in (1+4)D space $G'(E; \vec{P}, M)$ satisfy the relation $E^2 - c^2p_x^2 - c^2p_y^2 - c^2p_z^2 - m^2c^4 = 0$.

Note that this model differs from the analogous 5D theory developed in [6], in which mass is considered as the fifth coordinate in 5D time-coordinate-mass (matter) space. In such an approach it is impossible to build energy-momentum tensor due to mixing of mass coordinate with time and spatial coordinates.

In the proposed ESM the well-known energy-momentum 4-vector $\vec{P}(1 + 4) = (E/c; p_x, p_y, p_z) = (E/c; \vec{p})$ in Minkowski space $M(T; \vec{X})$ is transformed to the 5-vector $\vec{P}(1 + 4) = (E/c; \vec{p}, mc)$ in the extended space $G(T; \vec{X}, S)$ and becomes null for 5-vectors of a massive particle at rest $(mc; 0, mc)$ as well as for a massless particle $(\hbar \omega/c; \hbar \omega \vec{k}/c; 0)$ (here $\vec{k}$ is the unit vector in the particle propagation direction).

The basic predictions of general relativity can also be obtained in ESM. For instance, the following gravitational effects have been considered in [5]: the planet escape velocity, starlight redshift and deflection, and retardation of radar echo from Mars. It has been shown that it is possible to obtain the same formulae as in the general theory for the magnitudes of these effects in quite another way in the framework of ESM.

According to the ESM conception, any external influence applied to any material object can be described as a change in the appropriate refractive index $n$ at the location of this object (the introduction of a refractive index for the gravitational field is well known, see, e.g., [7]). A change in the refractive index causes reduction of energy, momentum or mass of the object. Formally, in ESM such a process is described by rotations in the planes $(T; \vec{X})$, $(\vec{X}; S)$ and $(T; S)$. We suppose that the weak gravitational field of a central massive body generates the refractive index $n(r) = 1 + \gamma M/rc^2$ in space (where $\gamma$ is the gravitational constant). The refractive index $n(r)$ depends on the gravitational field strength. This refractive index determines the motion of both massless (photons) and massive particles in space. Taking into account the appearance of a refractive index in space around a massive body, we then apply the technique of rotations in 5D extended space to calculate various interactions of external bodies with the gravitational field.

Let us, for instance, briefly show the way of obtaining the second space velocity in ESM. A massive body at rest is described in our model by the 5D vector $mc(1; 0, 1)$. The motion of a massive body in the gravitational field along the $x$-axes can be considered in the extended space $G(T; \vec{X}, S)$ as a motion in the plane $(\vec{X}, S)$. Consider the motion of this massive body from a point where the gravitational field is absent (where the refractive index is $n = 1$) to a point with the refractive index $n(r)$. This motion is described in EMS by the Euclidean rotation of a 5D vector in the $(\vec{X}, S)$ plane:

$mc(1; 0, 1) \rightarrow mc(1; -\sin \psi, \cos \psi)$

$= mc\left(1; -\frac{\sqrt{n(r)^2 - 1}}{n(r)}, \frac{1}{n(r)}\right)$.

Here we take into account that for massless particles...
(photons) the same rotation in the plane \((X, S)\) has the form
\[
\frac{\hbar \omega}{c} (1; \tilde{\lambda}, 0) \rightarrow \frac{\hbar \omega}{c} (1; \tilde{k} \cdot \cos \psi, \sin \psi).
\]
The velocity of this particle \(v = c \cdot \cos \psi\), hence the refractive index equals \(n = c/v = 1/\cos \psi\) [1].

Thus the total velocity gained by a massive particle is
\[
v = pc^2/E = c\sqrt{n(r)^2 - 1/n(r)} \approx \sqrt{2\gamma M/r}.
\]
Here we took into account that in the case of a weak gravitational field \(n(r) \approx 1\). This value coincides with the escape velocity if we substitute the radius of the Earth as \(r\).

In the framework of ESM, the 5-current \(\vec{\rho} = (\rho, \vec{j}, J_5)\) is built instead of the 4-current \(\vec{\rho} = (\rho, \vec{j})\) as well as the 5-vector potential \((\varphi, \vec{A}, A_S)\) instead of \((\varphi, \vec{A})\). With this 5-vector potential it is possible to build field strength tensor \(|F_{ik}|\) whose components are calculated in the usual way as \(F_{ik} = \partial A_i/\partial x_k - \partial A_k/\partial x_i, i, k = 0, 1, 2, 3, 4\). In the new 5 × 5 tensor we have not only the usual electromagnetic components \(E_x = F_{10}, E_y = F_{20}, E_z = F_{30}, H_x = F_{32}, H_y = F_{13}, H_z = F_{21}\), but also the new components \(Q = F_{40}, G_x = F_{41}, G_y = F_{42}, \) and \(G_z = F_{43}\). We relate the vector \(\vec{G}\) to the gravitational field.

In addition, the 5 × 5 second-rank energy-momentum-mass tensor \(|T^{ik}|\) is built in ESM [8] in the same way as the 4 × 4 energy-momentum tensor is built in the usual \((1+3)\)D field theory. The \(|T^{ik}|\) components can be found from the \(|F_{ik}|\) components by well-known formula
\[
T^{ik} = \frac{1}{4\pi} \left( -F^{il}F_{ik}^{\prime} + \frac{1}{4}g^{ik}F_{lm}F^{lm} \right),
\]
\(i, k, l, m = 0, 1, 2, 3, 4\).

Besides, an extended set of the Maxwell equations has been obtained [1, 2]. This set connects the field strength with the 5-current that gives birth to the field.

In empty Minkowski \((1+3)\) space \(M(T; \vec{X}) (S = 0)\), the fields are independent. But when we deal with a material medium, which means that the parameter \(S\) becomes nonzero, the two electromagnetic field and a new fields \(\vec{G}\) and \(Q\) form a unified field, and their components can interact with each other.

If we rotate 5D vectors, which correspond to 5D-particles in ESM, in the plane \((T; \vec{X})\), this rotation leads to mixing the particle momentum and the mass. On the other hand, the rotation in the plane \((T; S)\) mixes mass with energy, while the rotation in the plane \((\vec{X}; S)\) mixes momentum with mass.

Further on, we can apply such rotations to the 5D vector potential \((\varphi, \vec{A}, A_S)\), the field tensor \(|F_{ik}|\), and the fields \(\vec{E}, \vec{H}, \vec{G}, Q\). The fields \(\vec{E}, \vec{H}, \vec{G}, Q\) can formally be converted into each other under the same transformations in the planes \((T; \vec{X})\), \((T; S)\) and \((\vec{X}; S)\) [1, 2]. The transformation rules are described by introducing the parameters \(\vec{v}, v_s, \vec{u}\). These parameters determine the transition from one frame of reference to another [1, 2, 9]:

1) rotation in the \((T; \vec{X})\) plane is characterised by a velocity \(\vec{v}\), and the transformations of fields are
\[
\hat{E}' = \hat{E} + (1/c)[v, \hat{H}], \quad \hat{G}' = \hat{G} - (1/c)\hat{Q},
\]
\[
\hat{H}' = \hat{H} - (1/c)[v, \hat{E}], \quad \hat{Q}' = \hat{Q} - (1/c)(v, \hat{G});
\]

2) rotations in the plane \((T; S)\) are characterised by the velocity \(v_s\) along the coordinate \(S\), and the field transformations are
\[
\hat{E}' = \hat{E} + (v_s/c)\hat{G}, \quad \hat{G}' = \hat{G} + (v_s/c)\hat{E},
\]
\[
\hat{H}' = \hat{H}, \quad \hat{Q}' = \hat{Q};
\]

3) rotations in the plane \((S, \vec{X})\) are characterised by the parameter \(\vec{u}\), and this vectorial parameter describes reduction of the refractive index \(n\) as a result of motion in the direction of \(\vec{u}\); the fields are transformed according to the relations
\[
\hat{E}' = \hat{E} - \vec{u}\hat{Q}, \quad \hat{G}' = \hat{G} + [\vec{u}, \hat{H}],
\]
\[
\hat{H}' = \hat{H} + [\vec{u}, \hat{G}], \quad \hat{Q}' = \hat{Q} + [\vec{u}, \hat{E}].
\]

So, we see that the electromagnetic and gravitational fields can be converted to each other under the corresponding transformation in the planes \((T; \vec{X})\), \((\vec{X}; S)\), \((T; S)\).

In particular, when a moving massive charged particle is decelerated, falling into an external field or substance, it can produce a gravitational field. Such transformation of fields could, in principle, take place during various nuclear processes such as gamma or neutron de-excitation, pair annihilation or formation and so on.

To check this qualitative prediction, the following experimental setup has been proposed and recently realized. A relativistic 30 MeV electron beam of average power 450 W from a microtron is stopped in condensed material (e.g., a tungsten plate). A torsion pendulum with two massive parts 4 kg each and rather a long transverse rod (120 cm) is used to measure the emerging gravitational field. One of the pendulum shoulders is set very close to the stopping target — a possible source of the gravitational field created by the electrons’ deceleration, and another shoulder is apart from it. As usual, reflection of a laser beam (He-Ne laser with 632.8 nm wavelength) from a mirror mounted on a shoulder is used to detect the possible pendulum deflection. The light spot from the mirror is observed on a screen located 5 m apart from the mirror and is registered by a videorecording system with 15-fold optical gain to increase the measurement accuracy. The accelerator setup gives us a possibility, very useful for such a type of experiment, of stopping the electron beam as well in another target, located near the opposite part of the pendulum shoulder, which could drive the pendulum rotation in
another direction. A more detailed description of the experiments can be found in Refs. [2, 4].

The first tentative experimental results show that there is a correlation between switchin on the electron beam and the mean deviation of the pendulum from its equilibrium position as compared with a control run before and after the switch. It was also found that the deviation direction varies depending on which of the pendulum loads was near the stopping target. An additional evaluation was made by various methods of statistics, to prove that the deviations detected are statistically authentic. Thus, by the Pearson criterion, the probability of confident statistical distinction between the results of control measurements of pendulum oscillations as compared with the phases of exposure of a stopping target to relativistic electrons exceeds 99%. The force that could cause a displacement of the equilibrium position of the pendulum was also evaluated. The deflecting force was estimated to be between $10^{-8}$ N and $10^{-6}$ N.

We carefully checked experimentally various possible sources which could cause the pendulum deviations: mechanical vibrations due to operation of water and air pumps, magnetic and electric dc and ac fields, electrization of different parts of the installation. It was found that all these sources could not cause the pendulum rotation.

Certainly, these first experimental results on checking the ESM predictions are of preliminary nature and require much more substantial tests, which will be a subject of future experiments.

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