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Gravitational interactions of bodes from the point of view of different principles of equivalence

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ABSTRACT

The gravitational interactions of particles with positive, negative and imaginary masses are considered from the point of view of the Einstein Equivalence Principle (EEP) of inert and gravitational masses, as well as three other possible principles of equivalence based on the equality of the gravitational mass to the inertial mass module. Several interpretations of the imaginary movement are proposed. It is shown that, on the basis of EEP, particles with negative or imaginary negative mass will be scattered, but when they interact with particles of positive mass and with each other, "strings" ("dipoles" or "one-dimensional atoms") and "multidimensional atoms" can form. On the basis of three other principles of equivalence, the formation of such objects is impossible. Negative masses in these variants form colonies, with acceleration moving away from ordinary positive matter.

Keywords: equivalence principle, negatons, positons, negaons, posions, mnimons, negamnimons, imaginary mass, negative mass, imaginary acceleration, imaginary speed

1. INTRODUCTION

Modern laws of physics do not prohibit the existence of a substance with an imaginary mass [1-3]. An unwritten rule is known, jokingly called the "universal Gell-Mann principle", which states that in physics "what is not forbidden is necessarily present" or, at least, it can be. This rule made it possible to make a number of discoveries - from neutrinos to radio galaxies

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[2]. Particles with an imaginary mass are usually interpreted as particles always moving faster than the speed of light, J. Feinberg called them tachyons [3]. But other interpretations of imaginary masses are possible, for example, as masses of virtual particles of different sorts with negative or even imaginary energy, filling the physical vacuum.

Currently, at the suggestion of H. Bondi [4], in any theory of gravity, in accordance with the measurement method, it is customary to distinguish three types of mass: inert, passive gravitational, and active gravitational. An inertial mass is a mass that characterizes the body's ability to acquire one or another acceleration under the influence of non-gravitational forces applied to it. It is included in Newton's second law, the body acquires a certain acceleration under the action of the applied force

$$\mathbf{F}_{in} = F^{\alpha} = m_{in} a^{\alpha} \tag{1}$$

$$\mathbf{a} = \mathbf{F}_{in}/m_{in}, \tag{2}$$

where from

$$\mathbf{F}_{in} = m_{in}\mathbf{a}. \tag{3}$$

Passive gravitational mass of a body characterizes the impact of a gravitational field on it and is determined by the expression

$$F_{\alpha} = -m_p \frac{\partial U}{\partial x^{\alpha}} \tag{4}$$

Active gravitational mass m_a of a body characterizes its ability to create a gravitational field. Both gravitational masses are included in the formula of Newton's law of gravitation:

$$\mathbf{F}_g = -G\frac{m_p \cdot m_a \mathbf{r}}{r^3}, \tag{5}$$

where $\mathbf{F}_g$ – the attractive force of two bodies with masses m_p and m_a, G – the gravitational constant, $\mathbf{r}$ – a radius vector connecting the centers of these masses.

The Einstein Equivalence Principle (EEP) postulates the equality of all these types of masses:

$$m_{in} = m_a = m_p\ . \tag{6}$$

This principle corresponds to Newton's second law in the form of (3). Based on this principle, the mechanics of the interaction of particles with a negative mass with each other and with particles of a positive mass is derived in [1, 5]. Particles of negative mass, starting from ordinary matter with positive mass, and from each other, are scattered in the Universe. The work [5] describes the mechanics of particles with negative mass on the basis of the New Equivalence Principle (NEP) of inert and gravitational masses:

$$\begin{gathered} |m_{in}| = |m_a| = |m_p| \\ |m_{in}| = |-m_a| = |-m_p| = +m \end{gathered} \tag{7}$$

In this embodiment, particles with negative mass will be attracted to each other and repelled from ordinary matter, which will lead to the formation of huge colonies with negative mass, moving away from ordinary matter.

The aim of this work is to conduct a comparative analysis of the interaction of particles of imaginary and material mass with each other from the point of view of different principles of equivalence, so that on the basis of these results there is the possibility of choosing the best option when constructing physical theories of the Universe and proving its truth.

2. THE EQUIVALENCE PRINCIPLE FOR IMAGINARY MASSES

I.P. Terletsky [6] suggested that particles of positive mass be called positons, and of negative mass that obey EEP, called *negatons*. Correspondingly, it is proposed to call particles of negative mass obeying NEP negaons, and particles of positive mass, respectively, posions, and add the prefix "nega" to the terms of objects with negative mass: negaparticles, negamatter, negamaterial. Similarly, for the convenience of perception and decision-making, particles with an imaginary mass obeying EEP will be called mnimotons and negamnimotons, and obeying NPEs, respectively, will be called mnimons and negamnimons.

Determining the principle of equivalence (6), Einstein correlated it only with a substance with a positive mass and did not set out to cover hypothetically existing matter with a negative mass. In Newton's second law (3), inert mass acts as the quantity of matter. It plays the role of resistance to the movement of the body, regardless of whether it has a gravitational charge: positive or negative, since the inertia of the body is determined by the movement of the body relative to the entire Universe. Therefore, in order to take into account the behavior of negative masses, Newton's second law should be of the form:

$$\mathbf{F} = |m_{in}|\mathbf{a} \tag{8}$$

From the expression (8) it follows that for the inertia force the amount of matter in the body is important, and not the quantity and sign of the gravitational charge contained in the mass of this body. It is this circumstance that determined NEP in the form of (10) [5]. The new principle of equivalence can naturally be extended to imaginary masses, as well as to complex objects, the mass of which can be represented by hypercomplex numbers containing imaginary units of different nature. The module (norm) $|z|$ of a hypercomplex number

$$z = a + bi + cj + dk \ldots. + ny \quad , \tag{9}$$

where $\bar{z} = a - bi - cj - dk \ldots. - ny$ – is the conjugate hypercomplex number. This norm, called the Euclidean norm, is positive definite. In the monograph by A.A. Sazanov [7] points to the existence of the Lorentz scalar product of complex numbers. The functional square of the Lorentz scalar product is the square of the alternating Lorentz norm equal to half the sum of the squares of conjugate numbers, which accurately reproduces the signature needed to describe space-time$(+,\ -,\ \ldots\ ,\ -)$:

$$Lr(z) = \frac{1}{2}[z^2 + (\bar{z})^2] = a_0^2 - \sum_{j=1}^{m-1} a_j^2 \tag{10}$$

$$\|z\| = +\sqrt{\frac{1}{2}[z^2 + (\bar{z})^2]} \tag{11}$$

Idea A.A. Sazanov was extended to all these algebras. Thus, the module of the hypercomplex number was not the only one. And since we cannot experimentally verify or theoretically prove how the imaginary mass bodies will behave, then, as a working hypothesis, in accordance with the Gell-Mann principle, we should assume that there can exist bodies that obey the law (11), the module which is determined by both formula (10) and (11). Such bodies will obey the Euclidean Equivalence Principles (EuEP) or Lorentz (LEP), respectively. These principles apply the second Newton's law, respectively, in the forms:

$$\mathbf{F} = |z_{in}|\mathbf{a} \tag{12}$$

$$\mathbf{F} = \|z_{in}\|\mathbf{a}\ . \tag{13}$$

If we use the NEP formulas (7, 8), then for the Mnimon Equivalence Principle (MEP), instead of the hypercomplex number module (10, 11), it is necessary to take the coefficient modules of its components:

$$\begin{gathered} |a_{in}| = |a_a| = |a_p| \\ |b_{in}| = |b_a| = |b_p| \\ |c_{in}| = |c_a| = |c_p| \\ \cdots\cdots\cdots \\ |w_{in}| = |w_a| = |w_p|\ , \end{gathered} \tag{14}$$

and Newton's second law will then be related to each component:

$$\mathbf{F} = |a_{in}|\mathbf{a} \tag{15}$$

$$\mathbf{F} = |b_{in}|\mathbf{a} \tag{16}$$

$$\mathbf{F} = |c_{in}|\mathbf{a}$$

$$\cdots\cdots$$

$$\mathbf{F} = |w_{in}|\mathbf{a}$$

where $a_{in} = m_{in}$, if the real component of the mass, $b_{in}, c_{in}, \ldots w_{in} -$ the imaginary components of the mass; if the object has only imaginary mass, $b_{in} = im_{in}$ then.

So, for particles with an imaginary mass, three versions of the equivalence principle are proposed: based on NEP: PEM, EuEP, LEP. The most reasonable, at the moment, seems to be the PEM version that meets the formulas (7, 8, 14 - 16).

As already mentioned, inert mass m_i acts as the "quantity of substance". But the concept of "substance" is still not clear in science, and therefore the principles of equivalence based on NPEs are still hypothetical, as well as the postulated Einstein Principle of Equivalence. Which of these options is true, it will be possible to find out only after it is possible to detect and study substances with negative and imaginary mass, if they exist at all.

3. INTERPRETATIONS OF NEGATIVE AND IMAGINARY MOVEMENT

Under the negative and imaginary movement refers to the movement with a negative and imaginary speed and the same acceleration, respectively. A movement with negative speed and negative acceleration is a movement directed in the direction opposite to the action of force on the body.

In this paper, we will study interactions between bodies with positive or negative material mass and imaginary mass with an imaginary unit $i = \sqrt{-1}$ from the point of view of the principles of NEP and EEP. Particles of imaginary mass will be called, respectively: *i-mnimons*, *i-negamnimons*; *i-mnimotons*, *i-non-mnimonotones*.

If the action of inertia forces is directed towards the corresponding action of gravity forces, as well as the fact that the mass of each body is both active and passive mass, then for the purposes of our analysis, the equality of the gravitational interaction force (5) to the inertia force (3) should be written in the form:

$$F_g = -G\frac{m_1 \cdot m_2}{r^2} = F_{in} = -m_{in}a$$

$$F = G\frac{m_1 \cdot m_2}{r^2} = m_{in}a \tag{17}$$

where m_1 и $m_2 -$ are the masses of interacting bodies. Accordingly, the very second Newton's law (3) for real values of mass and force will look:

$$F = m_{in}a, \tag{18}$$

and for imaginary values of force, but real mass values, respectively:

$$i\bar{F} = m_{in}a. \tag{19}$$

Similarly, for real values of force and imaginary values of mass we get:

$$F = i\bar{m}_{in}a \tag{20}$$

and for imaginary values of force and imaginary values of mass, respectively:

$$i\bar{F} = i\bar{m}_{in}a \quad \text{or} \quad \bar{F} = \bar{m}_{in}a \tag{21}$$

A bar over the symbols of power and mass means that the imaginary unit is taken separately for the sign of force or mass.

For imaginary accelerations arising in a number of cases, and, consequently, speeds, the following hypothetical interpretations are formally possible:

{1} The imaginary (imaginary value) of acceleration or velocity is explained by the fact that a particle with an imaginary mass moves;

{2} Motion in an imaginary dimension of space, when it is assumed that the dimension of space has, in addition to three real dimensions, some other additional “imaginary” dimensions;

{3} Motion in an imaginary dimension of space when such a dimension is time; in this variant, the object itself, moving in an imaginary way, is generally at rest, but it is subject to the action of time, the object is aging, or, on the contrary, becoming younger if this time goes in the opposite direction;

{4} Motion in an imaginary dimension of space, when such a dimension is a compactified real dimension of space;

{5} Motion in an imaginary dimension of space, when such a dimension is a compactified real time-like dimension; this may mean that the object makes some cyclic changes with the corresponding local time for the duration of these cycles, and the alternating cycles themselves are already packed into one-dimensional ordinary time;

{6} The imaginary movement of an object is explained by the fact that the object itself is generally at rest, and another object is moving toward or away from it.

{7} The imaginary movement is explained by the fact that the object itself is at rest, and a space moves relative to it, which can be filled with some kind of medium, for example, “ether”.

{8} The imaginary movement is explained by the fact that the object itself is at rest, and the Absolute Space (AS) moves relative to it. This is not the same as an object moving relative to a resting AS, or if the object is moving relative to the AS, and the AS relative to the object at the same time.

{9} The imaginary movement is that the space itself is expanding or contracting, and both interacting objects stand still (or even somehow move). In this embodiment, the distance between interacting bodies varies, although there may not be any direct movement of bodies at all.

{10} The simplest interpretation of imaginary motion consists in a motion whose direction is perpendicular (or at an angle different from 2, where) to the direction of the line connecting the interacting bodies. In this embodiment, the actual distance between the bodies will be determined by the length of the shortest path between them, i.e. according to the hypotenuse of the corresponding right-angled, oblique, or obtuse-angled triangle.

{11} Imaginary motion is motion in spaces of parallel Universes or in parallel spaces of the same Universe. Each space corresponds to a corresponding imaginary unit.

Other interpretations are probably possible. Due to the fact that there are many qualitatively different imaginary units, many of these interpretations can be described by corresponding systems of imaginary numbers. The analysis of various interpretations and models of imaginary movement, and especially in the interpretation of {10}, shows that the "imaginary" movement is not so imaginary! In this interpretation, it is presented as a very real movement. Moreover, if we consider the imaginary movement from the standpoint of interpretations {9} and {10} at the same time, then they confirm each other. Indeed, if the imaginary attraction or repulsion of particles is considered as the movement along the hypotenuse of the corresponding triangle, whose vertices are in the initial positions of the particles and the final position of one of the particles, then this movement is represented as compression (reduction of the distance between bodies) or, accordingly, expansion of space (increased distance between bodies). In the future, when describing interactions, the results will sometimes be interpreted within the framework of the interpretations of {9} or {10}, but these interpretations do not claim to be fully quantitatively consistent with the model of reality.

3. 1. Interactions based on the Mnimon Equivalence Principle

Formulas (18 - 21) taking into account (7, 8, 15, 16) when using MEP are written in the form:

$$F = |m|a \tag{22}$$

$$\bar{F}i = |m|a \tag{23}$$

$$F = i|\bar{m}|a \tag{24}$$

$$\bar{F} = |\bar{m}|a \tag{25}$$

Let us introduce the following notation of force indices in Newton's second law indicating the mass value of the corresponding body: $\boxed{m}$ − for posions and positons; $\boxed{-m}$ − negaons and negatons; $\boxed{mi}$ − i-mnimons and i-mnimotons; $\boxed{-mi}$ − i-negamnimonons and i-negaamnimotons.

- **Two posions with mass.** A positive sign in formula (17) indicates that the posions will be attracted to each other. From formula (22), we have

$$a = \frac{F}{|m|} = \frac{F}{m} > 0, \tag{26}$$

whence it follows that the accelerations of the posions are directed towards each other, and, therefore, attraction will actually act between them.

- **Two negaons with** mass. From formula (17) we obtain that the non-gaons will be attracted to each other, and from (22) it follows

$$F_{\boxed{-m}} = |-m|a \tag{27}$$

$$a = \frac{F}{|-m|} = \frac{F}{m} > 0\,, \tag{28}$$

so that the negoons will also be attracted to each other, as well as the posions.

- **Posion mass and non-chaon mass – *m*.** From formula (17) we obtain that the sign of the interaction force is negative. This corresponds to repelling them from each other. The acceleration sign of each of the particles (20) is positive:

$$a = \frac{F}{|-m|} = \frac{F}{|m|} = \frac{F}{m} > 0, \tag{29}$$

therefore, such particles will actually be repelled from each other, forming colonies of matter with a positive and, accordingly, with a negative mass.

- **Two *i*-Mnimon c masses $\boldsymbol{mi}$.** By the formula (17) we obtain that i-mnimons must be repelled from each other. But with what acceleration? By the formula (24) we find that the acceleration will be negative and imaginary:

$$F_{\boxed{mi}} = i|\overline{m}|a\ , \tag{30}$$

$$a = \frac{F}{|\overline{m}|i} = -\frac{F}{|\overline{m}|}i = -\frac{F}{\overline{m}}i < 0\ , \tag{31}$$

This means that they will move towards each other, i.e., essentially be attracted (this is the same as repelling with a negative repulsive sign), but in an imaginary way. In the interpretation of {9}, this indicates that the attraction is caused not by the actual movement of the bodies, but by the compression of the space between them, which leads to a reduction in the distance between them.

- **Two *i*-negamnimon masses $\boldsymbol{mi}$.** Acting in a similar way as in the case of mnimons, we obtain:

$$F = G\frac{(-m_1 i)\cdot(-m_2 i)}{r^2} = -G\left(\frac{m^2}{r^2}\right) \tag{32}$$

$$F_{\boxed{-mi}} = |-\overline{m}|ia = \overline{m}ia, \qquad a < 0. \tag{33}$$

Thus, the interaction of non-hamnimons with each other is the same as that of mnimons: as if pushing from each other, they, in fact, are attracted to each other, albeit in an imaginary way.

- ***i*-Mnimon with mass $\boldsymbol{m_1 i}$ and posion with mass $\boldsymbol{m_2}$.** From (17) we have:

$$F = G\frac{m_1 i\cdot m_2}{r^2} = G\frac{m_1\cdot m_2}{r^2}i \tag{34}$$

we get that such bodies should be attracted to each other, but with imaginary force.
Let's see what their accelerations are. For the mnimon from (21, 25) we have:

$$i\overline{F} = |\overline{m}_1|ia, \tag{35}$$

whence follows

$$\overline{F}_{\boxed{mi}} = |\overline{m}_1|a;\quad a > 0. \tag{36}$$

Therefore, the mnimon should really be attracted to the poseion. For position from equality (21) we obtain

$$\bar{F}_{\boxed{m}}\, i = |m_2| a \;, \tag{37}$$

$$a = \frac{\bar{F}_{\boxed{m}}}{m_2} i > 0 \;. \tag{38}$$

Posion, thus, is also attracted to the imaginary, but with imaginary acceleration. From {9} it follows that the distance between them should be reduced both due to the actual movement of the imaginary, and due to the compression of space.

- ***i*-Mnimon with mass $m_1 i$ and negaon with mass $-m_2$.**

$$F = G\frac{m_1 i\cdot(-m_2)}{r^2} = -\,G\frac{m_1\cdot m_2}{r^2} i \;, \tag{39}$$

which corresponds to imaginary repulsion. To accelerate the negaon from (26) we obtain:

$$i\bar{F}_{\boxed{-m}} = |-m_2| a;$$

$$a = \frac{\bar{F}_{\boxed{-m}}}{|-m_2|} i > 0 \;, \tag{40}$$

therefore, the negoon does indeed repulse itself from the imaginary imaginary image. For the mnimon from (25) we have:

$$i\bar{F}_{\boxed{mi}} = \bar{m} i a, \tag{41}$$

whence follows

$$a = \frac{\bar{F}_{\boxed{mi}}}{\bar{m}} > 0. \tag{42}$$

This indicates that the mnimon is really pushing away from the negaon. Thus, the negoons and mnimons from each other scatter.

- ***i*-Mnimon with mass mi and *i*-negamnimon with mass $-mi$.**

$$F = G\frac{mi\cdot(-mi)}{r^2} = G\frac{m^2}{r^2} \tag{43}$$

It follows from (43) that they will be formally attracted to each other. The accelerations for both the mnimon and the negamnimon, determined from formula (24), will be negative and imaginary:

$$a = \frac{F}{i|\bar{m}|} = -\frac{F}{|\bar{m}|} i < 0 \tag{44}$$

Therefore, the distance between them will increase, in accordance with the interpretation of {9}, due to the expansion of space. This will lead to the formation of colonies of mnimons and colonies of negamnimons that are far removed from them.

- **Posion mass m_1 and i-negamnimon with mass $-m_2 i$.**

$$F = G\frac{m_1\cdot(-m_2 i)}{r^2} = -G\frac{m_1 m_2}{r^2}i \tag{45}$$

Formally, imaginary repulsion acts between them. For posions, applying (23), we obtain

$$a = \frac{i\bar{F}}{|m|} > 0, \tag{46}$$

which suggests that the positions will actually be repelled from non-gammones in an imaginary way. For nongamnimons they will act (25, 42), therefore, nongamnimons will also move away from posions due to the expansion of space (in accordance with {9}).

- **Negaon mass $-m_1$ and i-negamnimon mass $-m_2 i$.**

$$F = G\frac{(-m_1)\cdot(-m_2 i)}{r^2} = G\frac{m_1 m_2}{r^2}i \tag{47}$$

Formally, this is an imaginary attraction. For nygaons, formulas (23, 45) apply, and for negamnimones (23, 42), so these particles will really be attracted to each other, albeit in an imaginary way due to the compression of space.

3. 2. Interactions based on the Einstein Equivalence Principle

For comparison, we find particle interactions obeying the Einstein principle of equivalence. Newton's second law based on EEP is written by formulas (18 - 21).

- **Two positons with mass m.** From formulas (17, 18) we get that positons will attract each other.

- **Two negatons with mass $-m$.** From (17) it follows that they should be attracted. But from Newton's second law for negatons (18):

$$F_{\boxed{-m}} = (-m)a \tag{48}$$

It follows that their accelerations are negative $a < 0$, so that in reality they will repel each other and disperse throughout the universe.

- **Positon with mass m_1 and negaton with mass $-m_2$.**

$$F = G\frac{m_1\cdot(-m_2)}{r^2} = -G\frac{m_1\cdot m_2}{r^2} \tag{49}$$

From formulas (17, 49) it follows that repulsion must act between them. But the acceleration is positive for positons, and negative for negatons, therefore positons will repulse from negatons, and negatons, on the contrary, will be attracted to them. If, then repulsion will prevail, and the distance between the particles will increase, and if $m_1 < m_2$, then the particles will be attracted to each other. If the masses are equal, the particles will be at rest relative to each other.

- **Two mnimotons with mass mi.**

$$F = G\frac{\overline{m}i\cdot\overline{m}i}{r^2} = G\left(\frac{-\overline{m}^2}{r^2}\right) = -G\left(\frac{\overline{m}^2}{r^2}\right) \tag{50}$$

From equality (17, 50) it follows that the mnimotons must be repelled from each other. From Newton's second law for mnimotons (20):

$$F_{\boxed{mi}} = \overline{m}ia \tag{51}$$

It follows that their accelerations are negative and imaginary. Therefore, as a result of the interaction of the mnimotons, the distance between them is reduced, and their imaginaryness in the model {9} indicates a compression of the space between them.

- **Two negamnimotons with mass $-mi$.** From (17) it follows that the non-gamnimotons must be repelled from each other. From Newton's second law for them

$$F_{\boxed{-mi}} = -\overline{m}ia \tag{52}$$

follows that

$$a = \frac{iF_{\boxed{-mi}}}{\overline{m}} > 0\ . \tag{53}$$

For this reason, the distance between interacting non-gamnimotons will increase imaginaryly, which corresponds to the expansion of space.

- **Positon and mnimoton.**

$$F = G\frac{m_1\cdot\overline{m}_2}{r^2}i \tag{54}$$

$$iF_{\boxed{m}} = m_1 a \tag{55}$$

$$i\overline{F}_{\boxed{mi}} = i\overline{m}_2 a \tag{56}$$

From (17, 54) we obtain that the positon and the mnimoton must be attracted but with imaginary force. From (19, 55) it follows that for positon > 0 , therefore, it is really attracted to the mnimoton. For the mnimoton, formulas (21, 56) apply, from which it can be seen that its acceleration is positive, so that it will also be attracted to the positon in an imaginary way.

- **Negaton and mnimoton.**

$$F = G\frac{(-m_1)\cdot i\overline{m}_2}{r^2} = -\,G\frac{m_1\cdot\overline{m}_2}{r^2}i \tag{57}$$

From (57) we conclude that formally the negaton and the imaginary tone seem to repel each other.
And since

$$i\overline{F}_{\boxed{-m}} = -m_1 a; \quad a < 0 \tag{58}$$

Then the negaton will, in fact, seem to be attracted to the mnimoton. The mnimoton obeys the law (21), from which it follows that its acceleration is real and positive. From this, it follows that the mnimoton will be repelled from the negaton. Thus it turns out that the mnimoton actually moves away from the negaton, while the effect of the negaton leads to a reduction in the distance between them. Depending on which of the values m_1 or $\overline{m}_2$ is greater than the distance between the bodies will increase or decrease.

- **Positon and negamnimoton.**

$$F = G\frac{(m_1)\cdot(-i\overline{m}_2)}{r^2} = -G\frac{(m_1)\cdot(\overline{m}_2)}{r^2}i \tag{59}$$

From law (59) it follows that imaginary repulsion acts between them, and from (19) and from (21) it follows that the acceleration of the positon will be positive, but imaginary, and the acceleration of the negamnimoton is real and negative. Positon, i.e. will repulsively repulse from the negamnimoton, and the negamnimoton will be attracted to it. One of them will prevail depending on the ratio of their masses.

- **Negaton and negmnimoton.**

$$F = G\frac{(-m_1)\cdot(-i\overline{m}_2)}{r^2} = G\frac{(m_1)\cdot(\overline{m}_2)}{r^2}i \tag{60}$$

Law (60) formally states that these particles are supposedly attracted. And since for negatons it follows from (19) that $a < 0$, they will be imaginary repelled by negamnimotons. Negamnimotons, obeying (21), will also have negative acceleration, and therefore will also be repelled from negatons.

- **Mnimoton and negamnimoton.**

$$F = G\frac{(i\overline{m}_1)\cdot(-i\overline{m}_2)}{r^2} = G\frac{(\overline{m}_1)\cdot(\overline{m}_2)}{r^2} \tag{61}$$

In accordance with (61), these particles should be attracted to each other. But from equality (20) we obtain that their accelerations are imaginary and have different signs. Therefore, they will rest relative to each other with equal masses, and be repelled or attracted with their inequality.

3. 3. Euclidean Equivalence Interactions

- **Two posions; two negoons; posion and negaon.** Using formulas (9, 10, 12, 19), we obtain that the posions between themselves and the negaons among themselves will be attracted, and the posions and the negaons will repel each other.

- **Two mnimon; two nongamnimon.** Because the

$$F = G\frac{mi \cdot mi}{r^2} = G\frac{(-mi)\cdot(-mi)}{r^2} = G\left(\frac{-m^2}{r^2}\right) = -G\left(\frac{m^2}{r^2}\right), \quad (62)$$

Then the mnimons and negamnimons should be repelled among themselves, and since, by virtue of (12):

$$F_{\boxed{mi}} = |mi|a = ma; \quad a > 0 \quad (63)$$

$$F_{\boxed{-mi}} = |-mi|a = ma; \quad a > 0, \quad (64)$$

Then this repulsion will be valid.

- **Mnimon and negamnimon; mnimon and posion.** From (17) we conclude that the mnimon and posion, as well as the mnimon and negamnimon, should be attracted to each other. Formulas (17, 27, 63 and 64) confirm this.

- **Posion and negamnimon; negaon and mnimon.** From the formula (17) it follows that the posions and negamnimons, as well as the negons and mnimons, should be repelled from each other. And formulas (18, 27, 63, 64) confirm this.

- **Negon and negamnimon.** In accordance with (47), an imaginary attraction acts between them. Formulas (27, 64) confirm this.

3. 4. Interactions based on the Lorentz Equivalence Principle.

In accordance with formula (14), we note the following obvious equalities:

$$\|m\| = m; \quad (65)$$

$$\|-m\| = m; \quad (66)$$

$$\|mi\| = mi; \quad (67)$$

$$\|-mi\| = mi. \quad (68)$$

Newton's second law for the masses (65 - 68) can be written, respectively:

$$F_{\boxed{m}} = \|m\|a = ma, \quad (69)$$

$$F_{\boxed{-m}} = \|-m\|a = ma \tag{70}$$

$$F_{\boxed{mi}} = \|mi\|a = mia \tag{71}$$

$$F_{\boxed{-mi}} = \|-mi\|a = mia \tag{72}$$

- **Two posions; two negaons.** From formula (17) it follows that the posions must be attracted to the posions, and the negaons to the negaons. And from formulas (13) and (69, 70) it follows that their accelerations will be positive, which confirms the conclusion made above.

- **Posion and negaon.** It follows from formula (17) that posion and negaon must be repelled from each other, and formulas (13, 69, 70) confirm this.

- **Two mnimons; two negamnimons.** From formula (17) it can be seen that mnimons should be repelled from mnimons, and negamnimons from negamnimnons. Newton's second law for them can be written, respectively, by formulas (71, 72), from which it follows that their accelerations are negative and imaginary. Therefore, instead of repulsion, there will be an imaginary attraction between them.

- **Posion and mnimon.** From (27) we obtain that the posion and the mnimon must be attracted to each other, but with imaginary force. For a posion from (69), we obtain that its acceleration is positive and imaginary, which indicates its imaginary attraction to the mnimon. For the mnimon, equality (71) with an imaginary force will be:

$$iF_{\boxed{mi}} = \|mi\|a = mia, \tag{73}$$

whence it is positive. Therefore, the mnimon will also be imaginary attracted to the posion.

- **Posion and negamnimon.** Imaginary repulsion follows formally from (17). Formula (69) confirms the imaginary repulsion for posions. And from formula (72) for negaamnimons with an imaginary force

$$iF_{\boxed{-mi}} = \|-mi\|a = mia \tag{74}$$

It follows that their acceleration will be positive, which indicates a real repulsion of negaamnimons from posions.

- **Negaon and mnimon.** From (17) we obtain imaginary repulsion. Since for negoons from (70) with an imaginary force, it follows that the negoons will actually be imaginary repelled by the mnimons. From formula (73) for mnimons we obtain that their acceleration is positive. Therefore, they will be repelled by the negoons.

- **Negon and negamnimon.** In accordance with (17), an imaginary attraction acts between them. For negoons, by virtue of (70), this remains an imaginary attraction. For nonhamminons, by virtue of (74), due to the positiveness of their acceleration, attraction also arises.

- **Mnimon and negamnimon.** By virtue of (17), the mnimon and non-namnimon must be attracted. Formulas (71, 72) confirm this, but in an imaginary version.

4. DISCUSSION OF THE RESULTS

The interaction of particles obeying different principles of equivalence (positons with posions, negatons with negaons, etc.) is also not considered in this work. For convenience of perception and decision-making, the results obtained are presented in the form of Tables 1 - 4, in which the following notation is involved: m_a – active mass; m_p – passive mass; "+" Means that the distance between the bodies is reduced for the reason that they either move towards each other, or the space between the bodies is compressed; "–" means that the distance between interacting bodies increases due to the movement of bodies, or due to the expansion of space. The sign *i* in the tables means that at least one of the interacting particles moves imaginaryly.

Table 1. PEM-based particle interactions map.

Principle Equivalency Mnimons		m_a	m_a	m_a	m_a
		Posion	Negaon	Mnimon	Negamnimon
m_p	Posion	+	–	+*i*	–*i*
m_p	Negaon	–	+	–*i*	+*i*
m_p	Mnimon	+*i*	–*i*	+*i*	–*i*
m_p	Negamnimon	–*i*	+*i*	–*i*	+*i*

Table 2. Map of particle interactions based on EEP.

Einstein equivalence principle		m_a	m_a	m_a	m_a
		Positon	Negaton	Mnimoton	Negamnimoton
m_p	Positon	+	+, 0, –	+*i*	+, 0, –*i*
m_p	Negaton	+, 0, –	–	+*i*, 0, –	–*i*
m_p	Mnimoton	+*i*	+*i*, 0, –	+*i*	+*i*, 0, –*i*
m_p	Negamnimoton	+, 0, –*i*	–*i*	+*i*, 0, –*i*	–*i*

Table 3. Map of interactions of particles based on EuEP.

Euclidean Equivalency Principle		m_a Posion	m_a Negaon	m_a Mnimon	m_a Negamnimon
m_p	Posion	+	–	+	–
m_p	Negaon	–	+	–	+
m_p	Mnimon	+	–	–	+
m_p	Negamnimon	–	+	+	–

Table 4. Map of interactions of particles based on LEP.

Lorenz Equivalency Principle		m_a Posion	m_a Negaon	m_a Mnimon	m_a Negamnimon
m_p	Posion	+	–	$+i$	$-i$
m_p	Negaon	–	+	$-i$	$+i$
m_p	Mnimon	$+i$	$-i$	$+i$	$+i$
m_p	Negamnimon	$-i$	$+i$	$+i$	$+i$

From the Table 1 from the point of view of TEM, it follows that the positive and negative matter will pile up into separate colonies and, with acceleration, endlessly move away from each other, so that over time they will be beyond the horizon of events. Light from one of them will not reach the other, so that they may produce the effect of "dark matter". Matter with an imaginary mass behaves in a relatively similar, but imaginary way. It will form colonies of mnimons and, remote from them, colonies of negamnimons. In relation to ordinary matter, mnimons will be attracted to it, and negamnimons will be attracted to negative matter. The imaginary attraction in accordance with {9} is understood as the fact that the distance between the mnimons and posions, as well as between the negamnimons and negaons, will be reduced. And since the posions and negaons are repelled from each other, the stratification of matter will occur on colonies of posions with imaginary bound mnimons and similar colonies of negaons with negamnimons.

From the Table 2 from the point of view of the Einstein's Principle of Relativity, it follows that positive matter (positons) is attracted to itself, and negative matter (negatons), on the contrary, starting from itself and from positive matter, if the mass of the positon is greater than the mass of the negaton, is scattered throughout the Universe. If negaton is heavier than positon, then they will be attracted to each other. If their masses are equal, since the positon is repelled from the negaton, and the negaton is attracted to it with the same force, the distance between them remains unchanged. Therefore, between them one-dimensional atoms or strings can form, which can also be called dipoles. And since positons are attracted to each other, several positons can already form a nucleus. Several negatons, simultaneously attracted to this nucleus, but repelled from each other, will form a shell, and the entire structure, as a whole, will already be a multidimensional atom. As can be seen from the Table 2, the same situation, only in the imaginary version, arises in the case of the interaction of mnimotons with negamnimotons. Imaginary multidimensional atoms may arise here, the nuclei of which consist of mnimotons, and the shell consists of negamnimotons. Mnimotons themselves can form imaginary colonies, and negamnimotons, if they are not parked for positons, will be imaginary scattered.

In the case of mass inequality, when the negaton mass is substantially less than the positon mass, the negatons, attracted to nuclei consisting of adhering positons, and repelled from each other, can form not only one shell, but several, thereby forming multilevel atoms.

In a pair of negaton – negamnimotone, on the contrary, imaginary repulsion acts, negamnimotons are imaginary repulsive from each other, and negatons actually run away from each other, so such an agglomerate is completely unstable. The interactions of positons and mimotons due to their imaginary attraction, imaginary attraction of mnimotons to each other and the real attraction of negatons to each other form the corresponding formally stable agglomerate.

Since in one-dimensional atoms (strings) the positon is repelled from the negaton, i.e. moves away from him in space, and the negaton simultaneously manages to attract him, i.e. moves towards positon, then as a whole such a pair is moving relative to space in general, and in particular, relative to Absolute Space. In a one-dimensional atom, negatons surround the positon from all sides, therefore such an atom, moving as if in all directions at once, in fact, turns out to be at rest relative to space.

From the point of view of EuEP (Table 3), posions and negaons behave in the same way as in the case of PEM, will form scattered colonies. The mnimons and negmnimons individually will dissipate, but, attracted to each other, they can form multidimensional lattices and alternating structures: " – mnimon – negamnimon- mnimon – ". Similar structures filling the space can arise with the participation of posions and negaons (as well as positons and negatons).

The interactions between posions, between negaons and with each other based on LEP (Table 4), are the same as on the basis of PEM and EuEP, i.e. form scattered colonies. Mnimons and negamnimons are supposedly attracted to each other and to each other. This should lead them to stick together into a single imaginary lump or lumps. Similar lumps are formed from posions and mnimons, as well as negaons and negamnimons.

In the mnimon – negaon pair, the mnimons can form separate imaginary colonies, while the negaons will be imaginary away from these colonies and form the corresponding colonies of the negaons. In a similar manner, a pair of posions – negamnimon behaves: scattering colonies of posions and negamnimons form.

5. CONCLUSIONS

A comparative analysis of the results shows that an attractive feature of the new principle of equivalence is that the positive, negative and imaginary matter in these variants agglomerate into huge colonies of the corresponding sign, moving away from each other. Despite this, they can influence each other, which can manifest itself as the existence of "dark matter". However, the richest palette of possibilities is observed for objects obeying the Einstein Principle of Equivalence. From this point of view, the formation of one-dimensional strings and multidimensional atoms is possible, the appearance of which is not possible on the basis of NPE variants. Negative matter, however, cannot be collected in colonies, but will be scattered throughout the universe. Formally, it can also be an object of “dark matter”.

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