DECAY OF A SUPERBRADYON INTO A BARYONIC PARTICLE AND ITS ANTIPARTICLE.

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Abstract. Superbradyons are hypothetical elementary particles that can travel faster than light keeping real values of their mass and energy. They were suggested by Luis Gonzalez-Mestres. Superbradyons do not fit Einstein's theory of relativity. But they do fit the new theory of gravity which is called the 3D-brane universe model. Within the framework of this new theory we study the decay of a superbradyon into a baryonic particle and its antiparticle.

1. Introduction.

Superbradyons were first considered by Luis Gonzalez-Mestres in [1]. The term «superbradyon» was invented by him in [2]. In [3] Luis Gonzalez-Mestres have written the following formulas for the energy and momentum of a superbradyon:

$$E=\frac{m\,c_i^2}{\sqrt{1-\dfrac{|\mathbf{v}|^2}{c_i^2}}}\,,\qquad\qquad \mathbf{p}=\frac{m\,\mathbf{v}}{\sqrt{1-\dfrac{|\mathbf{v}|^2}{c_i^2}}}\,.\tag{1.1}$$

Here $\mathbf{v}$ is the velocity vector of the superbradyon in question and c_i is some speed constant greater than the speed of light. Using the index i for c_i in (1.1), Luis Gonzalez-Mestres emphasizes that there can be several sorts of superbradyons each with its own value of critical speed c_i.

Since the values of c_i are different from the speed of light, the formulas (1.1) are not Lorentz-invariant. Therefore they do not fit Einstein's special relativity. They do not fit Einstein's general relativity too. However there is a new theory of gravity which is called the 3D-brane universe model. The initial version of this theory was developed by me in the series of e-prints [4–9], see also conference abstracts [10–14] which are in Russian. The second version of the new theory was developed in my e-prints [15–18], see also conference abstracts [19–21] in Russian.

The difference between two versions of the new theory is that the initial version uses the so-called equidistance postulate (see [4]). In the second version this postulate is omitted (see [15]). Therefore the second version is more general and we refer the reader to it rather than to the initial version. As for superbradyons, they do fit both versions of the 3D-brane universe model (see [9] and [17]). Nevertheless,

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in this paper we study the decay of a superbradyon within the framework of the second version of the new theory, which is more general.

2. Superbradyons in the gravitational field.

In the 3D-brane universe model the gravitational field is described by two dynamical variables. They are the three-dimensional metric $\mathbf{g}$ and the positive scalar function g_{00}. These dynamical variables obey certain differential equations, see the equations (4.35) and (4.37) in [15] or the equations (4.49) and (5.16) in [16]. These equations are written in terms of three spatial variables

$$x^1 = x, \qquad\qquad x^2 = y, \qquad\qquad x^3 = z \tag{2.1}$$

which are called comoving coordinates and one time variable t which is called a brane time. The spacial comoving coordinates (2.1) can be complemented with the temporal coordinate produced in the following way:

$$x^0 = c_{\mathrm{gr}}\, t. \tag{2.2}$$

The constant c_{gr} in (2.2) is an analog of the speed of light. It is interpreted as the speed of gravitational waves. The speed of light itself is denoted through c_{el}, the speed of electromagnetic waves. Apart from c_{gr} and c_{el}, in the new theory some other speed constants are considered: c_{br} is the critical speed of baryonic particles and c_{nb} is the critical speed of non-baryonic ones. A priory all of these speed constants should not coincide with each other. However, in [17] the circular revolution of a non-baryonic particle around a Schwarzschild black hole was considered and the following formula for the angular frequency of such a rotation was derived:

$$\rho\,\omega^2 = \frac{c_{\mathrm{nb}}^2\,\gamma\,M}{c_{\mathrm{gr}}^2\,\rho^2}. \tag{2.3}$$

Here γ is Newton's gravitational constant (see [22]), ρ is the orbit radius of the particle, and M is the mass of the black hole. In the case a baryonic particle the formula (2.3) turns to the following one:

$$\rho\,\omega^2 = \frac{c_{\mathrm{br}}^2\,\gamma\,M}{c_{\mathrm{gr}}^2\,\rho^2}. \tag{2.4}$$

In the Newtonian limit the formula (2.4) should coincide with the classical one:

$$\rho\,\omega^2 = \frac{\gamma\,M}{\rho^2}. \tag{2.5}$$

Comparing (2.4) and (2.5), we derive

$$c_{\mathrm{br}} = c_{\mathrm{gr}}. \tag{2.6}$$

As for the equality $c_{\mathrm{br}} = c_{\mathrm{el}}$ analogous to (2.6), this equality is not yet derived within the new theory.

All known elementary particles are baryonic ones. Saying baryonic particle, here we assume not only baryons themselves, but all particles described by the Standard model (see [23]). Superbradyons are not found experimentally and not included into the Standard model. We treat them as non-baryonic particles and denote their critical speed through c_{nb}. Generally speaking, there are no restrictions for the value of the critical speed of non-baryonic particles. It can be greater than the speed of light, equal to the speed of light, or less than the speed of light. Following Luis Gonzalez-Mestres, we call superbradyons those non-baryonic particles whose critical speed is greater than the speed of light.

3. Energy and momentum of superbradyons and regular baryonic particles.

As it was said above, the gravitational field in the new theory is described by a 3D-metric $\mathbf{g}$ whose components constitute a symmetric 3×3 matrix

$$g_{ij} = g_{ij}(t, x, y, z) \tag{3.1}$$

and by a scalar function g_{00} with the same arguments

$$g_{00} = g_{00}(t, x, y, z). \tag{3.2}$$

Let's consider a non-baryonic particle (a superbradyon) with the rest mass M moving with the velocity $\mathbf{v}$. Its energy and its momentum are given by the formulas

$$E = \frac{M\,c_{\mathrm{nb}}^2}{\sqrt{g_{00} - \dfrac{|\mathbf{v}|^2}{c_{\mathrm{nb}}^2}}}\,, \qquad\qquad \mathbf{P} = \frac{M\,\mathbf{v}}{\sqrt{g_{00} - \dfrac{|\mathbf{v}|^2}{c_{\mathrm{nb}}^2}}}\,. \tag{3.3}$$

Similar formulas are written for the energy and momentum of a regular baryonic particle with the rest mass m moving with the velocity $\mathbf{u}$:

$$\varepsilon = \frac{m\,c_{\mathrm{br}}^2}{\sqrt{g_{00} - \dfrac{|\mathbf{u}|^2}{c_{\mathrm{br}}^2}}}\,, \qquad\qquad \mathbf{p} = \frac{M\,\mathbf{u}}{\sqrt{g_{00} - \dfrac{|\mathbf{u}|^2}{c_{\mathrm{br}}^2}}}\,. \tag{3.4}$$

The modules of velocity vectors in (3.3) and (3.4) are given by the formulas

$$|\mathbf{v}|^2 = \sum_{i=1}^{3}\sum_{j=1}^{3} g_{ij}\; v^i\, v^j, \qquad\qquad |\mathbf{u}|^2 = \sum_{i=1}^{3}\sum_{j=1}^{3} g_{ij}\; u^i\, u^j. \tag{3.5}$$

The components g_{ij} of the three-dimensional metric $\mathbf{g}$ in (3.5) are taken from (3.1). The quantity g_{00} in the denominators of the formulas (3.3) is taken from (3.2). As for the formulas (3.3), they are taken from [17], see the formulas (3.4) and (3.10) therein. The formulas (3.4) are written by analogy to (3.3).

4. Decay of a non-baryonic particle.

In this section we study the decay of a non-baryonic particle with the rest mass M, which can be a superbradyon of Luis Gonzalez-Mestres, into two baryonic particles. The non-baryonic particle is assumed to be neutral with respect to three baryonic interactions of the Standard model, i. e. with respect to electromagnetic, weak, and strong forces. Therefore the decay products should be a particle and its antiparticle. If these baryonic particles are composite ones, we assume them to be in their ground states with respect to internal interactions of their constituent parts. Under this assumption we can treat the decay products as two particles of the same rest mass m.

From the quantum point of view the particles participating in the decay have some uncertainties in their energies and momenta. These uncertainties lead to the uncertainties in the decay time and in the spacial location of the decay phenomenon. Passing to the classical limit $\hbar \to 0$, in this paper we assume that the decay is an instantaneous phenomenon that happens at some definite time t_0 and in some definite point O of the space. Let x_0, y_0, z_0 be some comoving coordinates of the decay point O. The new theory of gravitation, which we consider in this paper, is covariant with respect to changes of comoving coordinates

$$\begin{cases}\tilde{x}=\tilde{x}(x,y,z),\\ \tilde{y}=\tilde{y}(x,y,z),\\ \tilde{z}=\tilde{z}(x,y,z),\end{cases}\qquad\qquad \begin{cases}x=x(\tilde{x},\tilde{y},\tilde{z}),\\ y=y(\tilde{x},\tilde{y},\tilde{z}),\\ z=z(\tilde{x},\tilde{y},\tilde{z})\end{cases}\tag{4.1}$$

and with respect to the following changes of brane time variables

$$\tilde{t}=\tilde{t}(t),\qquad\qquad t=t(\tilde{t}).\tag{4.2}$$

Under the changes of comoving coordinates (4.1) the quantities (3.1) behave like the components of a twice covariant tensor, while the quantity (3.2) behaves like a scalar function. Under the time transformations (4.2) the quantities (3.1) behave like scalar functions, while the quantity (3.2) is transformed as follows:

$$g_{00}=\left(\frac{d\tilde{t}}{dt}\right)^{2}\tilde{g}_{00},\qquad\qquad \tilde{g}_{00}=\left(\frac{dt}{d\tilde{t}}\right)^{2}g_{00},\tag{4.3}$$

see (1.4) in [17]. Since $g_{00}(t,x,y,z)$ is a positive scalar function, applying (4.3), we can choose such a brane time variable t that

$$g_{00}=g_{00}(t_0,x_0,y_0,z_0)=1\tag{4.4}$$

at the decay point O and at the decay instant of time t_0. Due to (4.4) the formulas (3.3) and (3.4) are rewritten as follows:

$$E=\frac{M\,c_{\text{nb}}^2}{\sqrt{1-\dfrac{|\mathbf{v}|^2}{c_{\text{nb}}^2}}}\,,\qquad\qquad \mathbf{P}=\frac{M\,\mathbf{v}}{\sqrt{1-\dfrac{|\mathbf{v}|^2}{c_{\text{nb}}^2}}}\,,\tag{4.5}$$

$$\varepsilon=\frac{m\,c_{\text{br}}^2}{\sqrt{1-\dfrac{|\mathbf{u}|^2}{c_{\text{br}}^2}}}\,,\qquad\qquad \mathbf{p}=\frac{m\,\mathbf{u}}{\sqrt{1-\dfrac{|\mathbf{u}|^2}{c_{\text{br}}^2}}}\,.\tag{4.6}$$

Note that the formulas (4.5) and (4.6) are valid at the single point O and at the single instant of time t_0. Nevertheless they are enough for to calculate the decay that happens at that point and at that instant of time. Due to the momentum conservation law the momenta of our particles form a parallelogram, see Fig. 4.1. Through θ in Fig. 4.1 we denote the angle between the momentum vectors $\mathbf{p}_1$ and

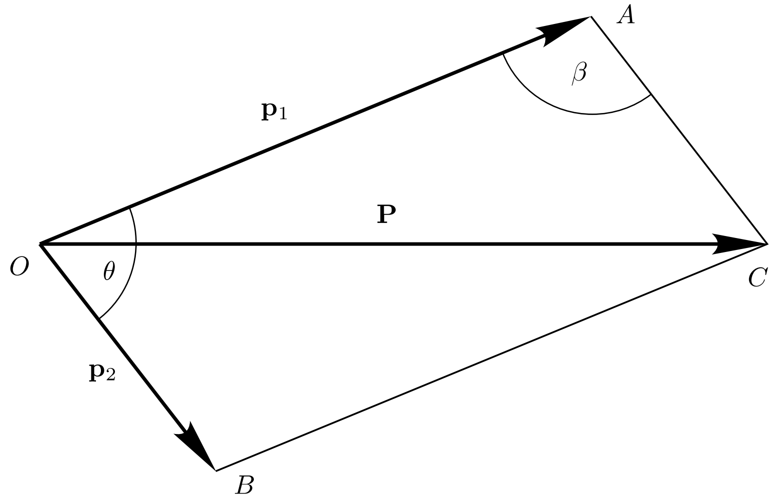

Fig. 4.1

$\mathbf{p}_2$ of the outgoing baryonic particles. The angle β is expressed through θ by means of the formula $\beta = 180° - \theta$. Taking into account the momentum conservation law

$$\mathbf{P} = \mathbf{p}_1 + \mathbf{p}_2 \tag{4.7}$$

and applying the law of cosines (see [24]) to the triangle OAC, from (4.7) we get

$$|\mathbf{P}|^2 = |\mathbf{p}_1|^2 + |\mathbf{p}_2|^2 + |\mathbf{p}_1|\,|\mathbf{p}_2|\cos\theta. \tag{4.8}$$

The quantities $|\mathbf{p}_1|$ and $|\mathbf{p}_2|$ in (4.8) are expressed through the velocities $\mathbf{u}_1$ and $\mathbf{u}_2$

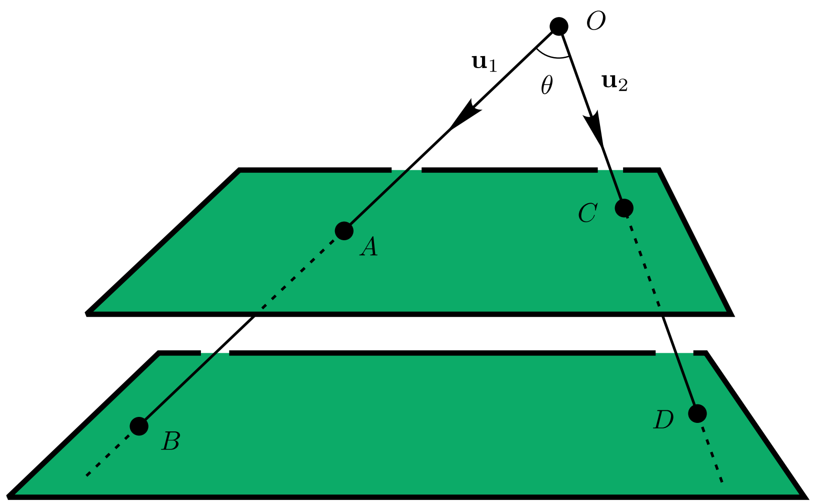

Fig. 4.2

according to the second formula in (4.6):

$$|\mathbf{p}_1|=\frac{m\,|\mathbf{u}_1|}{\sqrt{1-\dfrac{|\mathbf{u}_1|^2}{c_{\text{br}}^2}}}\,,\qquad\qquad |\mathbf{p}_2|=\frac{m\,|\mathbf{u}_2|}{\sqrt{1-\dfrac{|\mathbf{u}_2|^2}{c_{\text{br}}^2}}}\,.\tag{4.9}$$

The velocities $\mathbf{u}_1$ and $\mathbf{u}_2$ are obtained in an experiment from the detector data:

$$\mathbf{u}_1=\frac{\overrightarrow{AB}}{t_B-t_A},\qquad\qquad \mathbf{u}_1=\frac{\overrightarrow{CD}}{t_D-t_C}.\tag{4.10}$$

Two green planes in Fig. 4.2 are detector greeds. Each detector greed records the passage time of a particle through the greed and its crossing point. Two detector greeds provide data for the formulas (4.10). These data are enough in order to tell if two particles come from the same point O and to calculate the value of the angle θ in Fig. 4.2 as well as its cosine in the formula (4.8). Thus, due to (4.8), (4.9), and (4.10) we conclude that the quantity $|\mathbf{P}|$ in (4.8) is experimentally determined.

Now let's return to the formulas (4.5) and (4.6). From them we derive

$$E^2=|\mathbf{P}|^2\,c_{\text{nb}}^2+M^2\,c_{\text{nb}}^4,\qquad\qquad \varepsilon^2=|\mathbf{p}|^2\,c_{\text{br}}^2+m^2\,c_{\text{br}}^4.\tag{4.11}$$

The second equality (4.11) is written as two separate equalities for energies of two outgoing baryonic particles in the decay:

$$\varepsilon_1^2=|\mathbf{p}_1|^2\,c_{\text{br}}^2+m^2\,c_{\text{br}}^4,\qquad\qquad \varepsilon_2^2=|\mathbf{p}_2|^2\,c_{\text{br}}^2+m^2\,c_{\text{br}}^4,\tag{4.12}$$

Due to (4.9), (4.10), and (4.12) the energies ε_1 and ε_2 are also experimentally determined. These energies are used in writing the energy conservation law:

$$E=\varepsilon_1+\varepsilon_2.\tag{4.13}$$

Applying (4.13) to the first equality (4.11), we interpret it as a linear relationship associating two experimentally determined quantities E^2 and $|\mathbf{P}|^2$ with two unknown constant parameters c_{nb}^2 and $M^2\,c_{\text{nb}}^4$:

$$E^2=|\mathbf{P}|^2\,c_{\text{nb}}^2+M^2\,c_{\text{nb}}^4.\tag{4.14}$$

The parameters c_{nb} and M in (4.14) can be computed upon plotting experimental

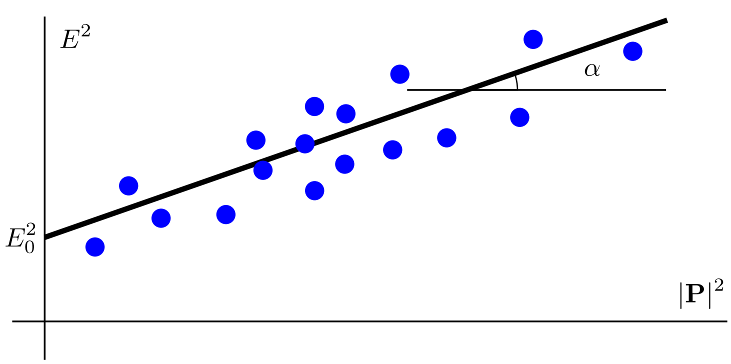

Fig. 4.3

data. The slope and the intercept of the straight line in Fig. 4.3 are obtained using the simple linear regression method (see [25]). Then c_{nb} and M are given by

$$c_{\mathrm{nb}} = \sqrt{\tan\alpha}, \qquad\qquad M = \frac{\sqrt{E_0^2}}{c_{\mathrm{nb}}^2}. \tag{4.15}$$

The formulas (4.15) mean that once the binary decay events of superbradyons and the products of their decay in the form of baryonic particle-antiparticle pairs are detected, the the rest mass of these superbradyons and their critical speed can be computed. However now these formulas have a theoretical significance only since the 3D-brane universe model is a non-Lorentz-invariant theory. The formulas (4.5), (4.6), (4.12), and (4.14) are associated with comoving coordinates and with some special choice of the brane time providing the equality (4.4). Their transformation to some Earth-based coordinates and/or to some satellite-based coordinates is a problem that will be studied separately.

5. Dedicatory.

This paper is dedicated to my sister Svetlana Abdulovna Sharipova.

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