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Electron Trembling as a Result of Its Stationary Motion in an Extra Space along Helical Line of the Compton Radius with the Speed of Light ("Zitterbewegung" in Multidimensional Space)

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Short Communication

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ABSTRACT

Because there is additional space in which the observed three-dimensional Universe expands, it is believed that elementary particles move at the speed of light in full space in a vicinity of a hyper-surface of three-dimensional sphere that is our Universe. Any interpretation of a spin and isotopic spin of electron requires at least three additional spatial dimensions. As applied to six-dimensional space, the simplest interpretation of the Heisenberg's uncertainties relation, de Broglie waves, Klein-Gordon equation, electron proper magnetic moment, CPT-symmetry, spin, and isotopic spin is consistent with the results of the theory of relativity and quantum mechanics. Taking into account the movement of elementary particle (at the speed of light) along a helical line of Compton radius, when the axis of the helix is placed on that hyper-surface, we find a trajectory of the particle.

Keywords: Zitterbewegung; electron; helical trajectory; 6D-space.

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1. INTRODUCTION

The quantum theory of "trembling" of an electron (Zitterbewegung) is based on the use of the Dirac equation [1,2]. However, instead of this, it is simpler and more visual to take into account the presence of additional dimensions of space and forces of the Lorentz type that hold elementary particles on finite orbits of Compton radius with rotation centers located on the hyper-surface of the three- dimensional sphere, which is our Universe [3,4]. In this case, the formulas of Newtonian mechanics are applicable to six-dimensional space.

The theory of relativity uses space-time (pseudo-Euclidean) and an imaginary unit. However, in the multidimensional interpretation of the Lorentz transformations, space-time and the imaginary unit are not claimed if elementary particles move in full space at a fundamental speed (c) (the upper limit of the speed of light) at Compton distance $a=\hbar/(mc)$ from the three-dimensional space X of observed Universe. Moreover, in the projection onto the additional space, such a motion is finite, which allows microscopic bodies not to leave the three-dimensional space X, but to move freely in it. Here, m is the mass of the particle, $h=2\pi\hbar$ is the Planck constant. And with the assumption that the proper time of an elementary particle is proportional to the length of the path traveled by it in additional space Y.

2. HEISENBERG'S UNCERTAINTIES RELATION AND de BROGLIE WAVES WITHOUT USING OF THE WAVE FUNCTIONS AND WAVE PACKETS

Our three-dimensional Universe is isotropic and homogeneous at distances of more than 300 million light years [3]. This means that on this scale the three-dimensional Universe does not have distinguished points, its curvature at all points is the same, and therefore it is a three-dimensional sphere and can only be located and expanded in the space of a higher number of spatial dimensions [5,6]. The length of the large circle of the Metagalaxy passing through the points of its boundary (particle horizon) can be taken as such a characteristic size. The main curvature of the Universe as a three-dimensional sphere is defined as a unit divided by the radius of this sphere. Today's radius of the Universe is 7100 Mpc. The scale of heterogeneities in the Universe is 100,000 times smaller than the characteristic size of the Metagalaxy [3]. Six-dimensional cosmology gives for the radius of the Metagalaxy (the observable part of the Universe) a value of 3980 Megaparsec [4]. As the Universe expands, its curvature tends to zero relatively quickly. The geometric and physical characteristics of the three-dimensional Universe are found by the formulas of the cosmological model under consideration, based on the principle of simplicity [7] with fixed parameters of the theory. These parameters are chosen so that the deviations of all compared values from each other were minimal.

A simple interpretation of the spin and isotopic spin requires at least three additional spatial dimensions. The complete space is assumed to be six-dimensional, since a simple interpretation of the electron spin and isospin is obtained. Therefore, the projections dx and ds of a displacement of a particle moving at the fundamental speed of light in full space, respectively, on the subspaces X and Y, are related by the Pythagorean theorem: $(cdt)^2=ds^2+dx^2$ where cdt is the displacement of a particle in full space in time dt. From here we get the metric of the theory of relativity: $ds^2=(cdt)^2-dx^2$.

Under the assumption that the proper time of an elementary particle is proportional to the path length traveled in extra space Y and all elementary particles move in full space at a fundamental speed (c), the Lorentz transformations are obtained elementarily [8-11].

The simplest object in six-dimensional Euclidean space is the five-dimensional sphere of perturbations in this space. The intersections of three expanding five-dimensional spheres are three expanding four-dimensional spheres, the mutual intersections of which form three expanding three- dimensional spheres. One of them is our three-dimensional Universe.

If the formulas of Newtonian mechanics are attributed not to three-dimensional, but to six-dimensional space, then the formulas of the special theory of relativity and quantum mechanics are obtained, provided that the proper time of an elementary particle is proportional to the path length traveled in additional space. So

that the observed interactions of elementary particles can occur, the particles are hold in a Compton neighborhood of our Universe by cosmological forces such as Lorentz forces perpendicular to our Universe. The role of the charge in them is played by the mass of the particle in a cosmological magnetic type field, oriented along the radius of the Universe.

A simple interpretation of the spin and isotopic spin requires at least three additional spatial dimensions. As well, a simple multidimensional interpretation of the Heisenberg's uncertainties relation, de Broglie waves, the Klein – Gordon equation, the proper magnetic moment of the electron, CPT-symmetry, and the presence of a minimum of angular sizes of the same binary stars depending on their redshift [4] is obtained without using of the wave functions and wave packets. Heisenberg's uncertainties relation is due to uncertainties of coordinates and moments of a particle in *Y*. In fact, let the directrix of a motion tube of a particle is displaced in the plane y_2, y_3. Then projections of the momentum of a particle on axes y_2 and y_3 and coordinates of the particle along this axes are equal to

$$p_{y2} = -mc\sin\phi \quad , \quad p_{y3} = mc\cos\phi \quad ,$$

$$y_2 = \frac{\hbar}{mc}\cos\phi, \qquad y_3 = \frac{\hbar}{mc}\sin\phi,$$ where ϕ is the angle of a turn of the particle about the axis of tube reckoned from the axis y_2. Average over ϕ values of coordinates and projections of the momentum are equal to zero, but their mean-square values are equal to

$$\left\langle y_2^2 \right\rangle = \left\langle y_3^2 \right\rangle = \frac{1}{2}\left(\frac{\hbar}{mc}\right)^2 ,$$

$\left\langle p_{y2}^2 \right\rangle = \left\langle p_{y3}^2 \right\rangle = \frac{1}{2}(mc)^2$, whence one finds seeking relation $\left\langle p_{y2}^2 \right\rangle \cdot \left\langle y_2^2 \right\rangle = \left\langle p_{y3}^2 \right\rangle \cdot \left\langle y_3^2 \right\rangle = \hbar^2/4$ [8,11]. Whence, in distinct of Heisenberg's inequality, it follows an exact equality: $p_{y2}^2 + p_{y3}^2 = (mc)^2$,

$y_2^2 + y_3^2 = (\hbar/mc)^2$,

$\left(p_{y2}^2 + p_{y3}^2\right)\left(y_2^2 + y_3^2\right) = \hbar^2$.

3. HELICAL TRAJECTORY OF ELEMENTARY PARTICLE IN MULTIDIMENSIONAL SPACE

Fig. 1 shows the helical trajectory (1) of an elementary particle satisfying Fermat principle and moving in the mixed subspace xy_2y_3 of full space along a helical line at the fundamental speed of light on a tube of Compton radius $a = \hbar/(mc)$, The axis of this helix is located in the space X. (2) is yet one helix, passing through this particle at right angle to its trajectory, is the helical line of the same proper time of the particle and moving with the speed of de Broglie waves; its step is equal to the de Broglie wavelength.

All directions in the space Y are perpendicular to any direction in the three-dimensional space X. An elementary particle in six-dimensional Euclidean space moves along a helical line with the fundamental speed of light the Compton radius distance $a = \hbar/(mc)$ from the axis of this line.

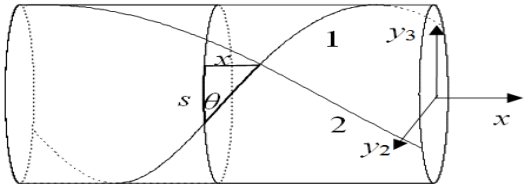

Fig. 1. It shows the helical trajectory (1) of a particle moving at the fundamental speed of light on a tube of Compton radius $a = \hbar/(mc)$ with an axis of this helix located in our space X. (2) is yet one helix, passing through this particle at right angle to its trajectory, is the helical line of the same proper time of the particle and moving with the speed of de Broglie waves; its step is equal to the de Broglie wavelength

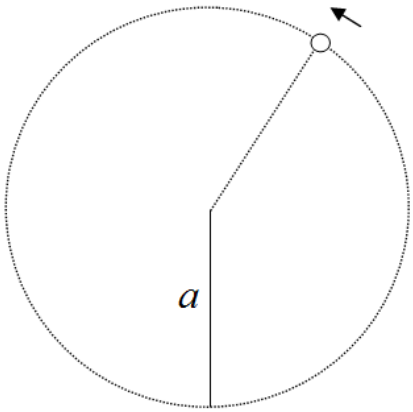

Fig. 2. Electron rotates in a circular orbit

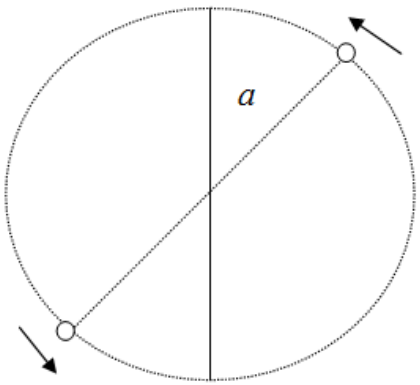

Fig. 3. Two electrons on one orbit rotate with the same momentum

The projection of elementary particle on the axis of the tube moves with a speed $v = c\sin\theta$, revolution around the axis of the helix is $T = 2\pi a/(c\cdot\cos\theta) = h/(mc^2\cdot\cos\theta)$. Whence it follows that the cyclic frequency is $\omega_1 = 2\pi/T = c\cdot\cos\theta/a = mc^2\cdot\cos\theta/\hbar$ Hz. If the particle in question is an electron, then for the case $v = 0$ $\cos\theta = 1$, $\omega_1 = c/a = mc^2/\hbar = 7.7634408\cdot10^{20}$ Hz, $a = c/\omega_1 = 3.861526\cdot10^{-11}$ cm at relative accuracy of 10^{-9}.

This shows that the analyzed phenomenon is uniform rotation of the electron in the simplest case at the speed of light in a circular orbit of Compton radius and with a constant cyclic frequency in the additional space. In addition, two electrons moving in a common circular orbit at a distance $2a = 2\hbar/(mc)$ of a diameter from each other and with a common centre of rotation, when electrons in question are mirror- symmetric with respect to each other anytime, give a cyclic frequency equal to $\omega_2 = 2\omega_1 = 1.55268816\cdot10^{21}$ Hz. However, from due to the mirror-symmetric position of electrons in orbit, their centre of mass coincides with the centre of rotation and therefore, there are no oscillations of the trajectory at the cyclic frequency ω_2.

It should be noted that, based on his cosmological and physical model with one additional spatial dimension of full space, in which all elementary particles move at the speed of light, I. A. Gribov explains the waveguide properties of space, relativistic and quantum effects.

4. CONCLUSION

M. B. Heaney poses the question in his article [2]: “But why should a single electron in free space (i.e., without field sources) and in the absence of forces acting on it, should spontaneously experience moving back and forth at the speed of light? It seems unphysical. Free-particle trembling is an insoluble mystery in the framework of the conventional interpretation of quantum mechanics.” However, an elementary particle can be free from forces acting in the observed three-dimensional space, not from forces like Lorentz acting in an additional space Y. Centripetal force such as Lorentz force in orbit in Y is balanced by centrifugal force in Y. If a magnetic type field oriented along the radius of the Universe suddenly shuts off, centripetal forces would disappear, and then all elementary particles would leave their orbits of with the speed of light and our three-dimensional Universe would be empty.

The considering uniform motion of elementary particles is their rotation in additional space along the orbits of Compton radius, in the simplest case at the speed of light, with the centre of rotation placed on an expanding three-dimensional sphere. Particles are hold in finite orbits by centripetal forces such as the Lorentz force in a field of the magnetic type, oriented along the radius of the Universe, where the mass of the particle plays the role of the charge, and centripetal and centrifugal forces cancel each other out. However, uniform movement along a helical line or around a circle is not, unlike chaotic, a trembling. It can only be called trembling conditionally when the movement in additional space is not taken into account. More precisely, it could be called pseudo- trembling.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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