Limiting the speed of light in a vacuum and cosmological paradoxes.

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Abstract: Using the particle-wave dualism of microparticles, it is strictly shown that the Universe has a limiting speed of movement of elementary particles, which is equal to the speed of light in vacuum. Since all material bodies are composed of microparticles, therefore, no object in the Universe can move faster than the speed of light. Further, using the limit of the speed of light in the Universe, the photometric and gravitational paradoxes are explained (Olbers' and Bentley's paradoxes).

Keywords: particle-wave dualism, elementary particle, limiting speed of motion in the Universe, speed of light in vacuum, Olbers' paradox, Bentley's paradox.

INTRODUCTION.

Let us recall that in Einstein's STR, the limit of the speed of light in vacuum is actually pustulated. To be more precise, then from the postulate of causality, and the postulate of the STR about the independence of the speed of light from the choice of the inertial frame of reference, it strictly follows that the speed of light in vacuum is ultimate. But, it can be shown that the Universe must have the limiting speed of particle motion (rest mass is not zero), strictly follows from quantum mechanics. More precisely, from the wave-particle dualism. Wave-particle dualism is a property of microparticles, which in some conditions manifest themselves as classical waves, and in other conditions - as classical particles. This is how electrons and light behave, and all elementary particles. That is, all quantum objects.

"In reality, quantum objects are neither classical waves, nor classical particles, exhibiting the properties of the first or second only depending on the conditions of the experiments that are carried out on them. The corpuscular-wave dualism is inexplicable in the framework of classical physics and can be interpreted only in quantum mechanics" [1].

Louis de Broglie developing idea about the dual nature of light, in 1923 put forward a hypothesis about the universality of the particle-wave dualism [2]. According to de Broglie, not only photons, but also electrons, and any other particles of matter, have both corpuscular and wave properties. Therefore, each micro-object is associated, on the one hand, with corpuscular characteristics (energy and momentum), and, on the other hand, with wave characteristics (frequency and wavelength). This ratio is expressed in the famous formula of Louis de Broglie.

$$\lambda = h / (m * v)$$

One fundamental conclusion follows strictly from de Broglie's formula: the de Broglie wave is matched to any moving object of the microcosm. This means that any moving elementary particle is not a classical particle (corpuscle), moreover, it (microparticle) is also not a classical wave. If we analyze this motion of a microparticle, then it is easy to show that in the Universe there is a limiting speed of movement of microparticles. And since all objects consist of microparticles, this means that no object in the Universe can move faster than the maximum speed of movement. We also note that in the general case, we get exactly the limiting velocity of the microparticle movement. And the transition to the speed of light occurs with further use of the Einstein equation ($E = m * c^2$). So, let's present the conclusion.

RESULTS AND DISCUSSION.

Suppose a microparticle of mass m0 moves with a velocity Vg. Then, according to the de Broglie formula, such a microparticle is assigned a de Broglie wave of a certain length λ.

$$\lambda = h / (m0 * Vg)$$

where λ - de Broglie wavelength,

m0 - mass of the microparticle,

Vg - group velocity of a wave, or microparticle velocity.

The de Broglie wave, like an ordinary wave, has a certain phase velocity Vf, which is expressed in terms of frequency and wavelength.

$$Vf = \gamma 0 * \lambda$$

where Vf - phase velocity of a wave,

γ0 - wave frequency.

Let us also recall that the idea of wave-particle dualism of microparticles is a consequence of de Broglie's hypothesis about a periodic process in an elementary particle. Louis de Broglie suggested that for an electron there is a certain periodic process that takes place with a frequency γ. We quote de Broglie [2, p. 203 (About frequency of the electron)]:

«In quantum theory, I assumed that there is a periodic process associated with the electron as a whole (the material point). This process for an observer stationary relative to an electron would occur over the whole space with the same phase and would have a frequency γ...».

Louis de Broglie wondered: if there is a periodic process associated with the electron, then what will the external observer see?

Pondering this question, de Broglie realized after a while: the outside observer will see the wave! It is in this way that de Broglie waves entered modern science. Here is how Georges Lochak describes it [2, p. 62]:

"...At the end of the summer of 1923, he told me: "A great light suddenly dawned on my mind" [19].

Realizing that the lag of the clock characterized oscillations inside the particle, he associated them with vibrations of the same frequency, but covering the whole space. And he showed that if an observer sees a particle in motion, then these spatial vibrations will seem to him waves propagating faster than a particle...

Changing both quantities in the same way, we find that the particle mass and wave frequency can now remain connected by the same relationships for all observers in accordance with the principle of relativity... However, de Broglie emphasized that this wave, moving faster than a particle, does not carry energy. It thus remains attached to the particle".

Considering the above about the periodic process in an elementary particle, it is obvious that the de Broglie wavelength is expressed through the frequency of the periodic process and the phase velocity of the wave.

$$\lambda = Vf / \gamma 0$$

Therefore, de Broglie's formula will be written as.

$$\lambda = h / (m0 * Vg)$$

$$Vf / \gamma 0 = h / (m0 * Vg)$$

$$m0 * Vg * Vf = h * \gamma 0$$

Where do we get:

$$Vg * Vf = (h * \gamma 0) / m0$$

Note that on the right side of the equation we only have constants, since both $\gamma 0$ and m0 are constants for a particular particle. Therefore, for a specific microparticle, we can write:

$$Vg * Vf = const$$

That is, during the movement of a microparticle (more precisely, an elementary particle), the product of the velocity of a microparticle by the phase velocity of the de Broglie wave is a constant value. Let us also recall that the velocity of a microparticle is always lower than the phase velocity of the de Broglie wave, this follows from the very essence of the considered periodic process. Therefore, with an increase in the velocity of a microparticle, the phase velocity of the wave will decrease. And the more we increase the velocity of the microparticle, the more the phase velocity will fall, and the more it (Vf) will approach the velocity of the microparticle (Vg). And at a certain limiting velocity of the microparticle, the phase velocity of the de Broglie wave will be equal to the velocity of the microparticle.

$$Vlimit = Vg = Vf$$

Thus, proceeding from the wave-particle duality, we have obtained the fact of the existence in the Universe of the upper limit of the speed of microparticles (more precisely, elementary particles). The microparticle cannot overcome this speed limit in any way. Since, when the microparticle overcomes the limiting velocity, the phase velocity of the de Broglie wave will be lower than the velocity of the microparticle, and given the essence of the periodic process, this is impossible (in elementary particles, according to de Broglie). Therefore, any material bodies in the Universe will also be limited by this limiting speed, since all material bodies, ultimately, consist of elementary particles.

To quantify the limiting speed of movement of material bodies, it is necessary to equalize the energy according to Planck and energy according to Einstein. And then use in the formula obtained earlier.

$$E = h * \gamma 0 = m0 * c^2$$

$$Vg * Vf = (h * \gamma 0) / m0 = E / m0$$

$$Vg * Vf = m0 * c^2 / m0$$

$$Vg * Vf = c^2$$

From the last, well-known equation, it strictly follows that the limiting speed of movement of material bodies in the Universe is the speed of light in vacuum. Since, upon reaching the limiting velocity of microparticles, the group and phase velocities will be equal (Vg = Vf).

$$Vlimit = Vg = Vf = c$$

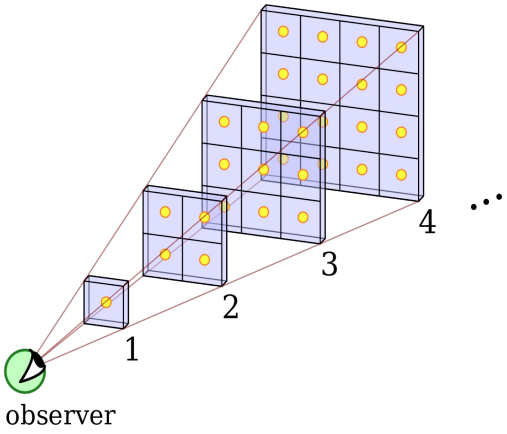
It should be specially noted that the speed of light in a vacuum, as the limiting speed of movement (numerical value), is obtained when we use the Einstein formula ($E = m*c^2$). And this is true. But,

the existence of an upper limit of the speed of elementary particles strictly follows from the formula of Louis de Broglie and the very fact of the existence of a periodic process in elementary particles, that is, from the very fact of the existence of wave-particle dualism. Therefore, it can be argued that the existence of a true limit of the speed of movement of elementary particles (in the general case of all material bodies in the Universe) is a consequence of the elementary structure of microparticles (that is, a consequence of their structurelessness), which manifests itself in the form of wave-corpuscular dualism. Here it is impossible not to recall the fact that numerically the speed of light in a vacuum is determined by two constants: dielectric and magnetic ($c = 1/(\varepsilon*\mu)^{0.5}$), which confirms the above (elementary particles will always have certain magnetic and electrical effects).

Olbers' paradox.

The Olbers' paradox is a photometric paradox, which consists in the fact that if the Universe is uniformly filled with stars, and infinite in space and time, then the brightness of the sky (including the night) should be equal to the brightness of the solar disk. That is, looking at the sky we should see a solid bright Sun. This paradox is called the Olbers' paradox, in honor of the German astronomer who attracted attention to him in 1823 [3]. Earlier, in 1744, the Swiss astronomer Chaiseau, in an appendix to the article, gives the first full formulation of the paradox [4].

“In an infinite static Universe, the whole space of which is filled with stars, every ray of vision should end with a star, similar to how in a dense forest we find ourselves surrounded by a "wall" of remote trees. The flux of radiation energy received from a star decreases inversely with the square of the distance to it. But the angular area (solid angle) occupied by each star in the sky also decreases inversely with the square of the distance, which implies that the surface brightness of the star (equal to the ratio of the energy flux to the solid angle occupied by the star in the sky) does not depend on the distance. Since our Sun is a typical star in every respect, the surface brightness of the star should, on average, be equal to the surface brightness of the Sun. When we look at some point in the sky, we see a star with the same surface brightness as the sun; the surface brightness of a neighboring point should be the same, and in general at all points of the sky, the surface brightness should be equal to the surface brightness of the Sun, since there must be some kind of star at any point in the sky. Therefore, the whole sky (regardless of the time of day) should be as bright as the surface of the Sun" [5].



In modern cosmology, the photometric paradox is explained by the finiteness of the age of the Universe, and the finiteness of the speed of light. Since the age of the Universe is only 13 billion years, the light from the farthest stars that we can observe (in principle) goes about 13 billion years. That is, the stars are located at a certain distance from us, and not at arbitrarily large distances. Due to the finiteness of the speed of light, light has not yet reached us from very distant stars (the existence of the Universe is not enough). Therefore, a star will not correspond to each point of the sky: firstly, the light has not reached, and secondly, the Universe is not infinite. This is the theory. But, here everything is not simple.

It is quite obvious that if the life of the Universe is not 13 billion years, but, for example, 1000 billion years (or much more), then our sky may very well turn into a continuous Sun. Since, with the increasing age of the Universe, the number of stars whose light reaches us will also increase. In fact, a very old dynamic Universe will not differ much from the stationary Universe. Thus, at a certain age of the expanding Universe, our sky must inevitably turn into a continuous Sun. Moreover, such a sky will be even at night. Naturally, in this case, life on Earth cannot exist. We came to another paradox that in a dynamic Universe, life can exist only in a very early period. But, our Universe is designed in such a way that life feels comfortable, therefore, life in the Universe can always arise and evolve. And the Olbers' paradox can only be explained by the finiteness of the speed of light in a vacuum, without the expansion of the Universe, the Big Bang, etc.

Since the speed of light is finite, we will always see a limited part of the Universe. This strictly follows from the fact, that galaxies, as they move away from us, have an ever greater speed [6, the Hubble-Lemetre law]. So, at a certain distance from us, galaxies will have a speed equal to the speed of light. This will be the border of our visible part of the Universe (our ball). Beyond this boundary, the Universe exists, but for us it is not visible, since we cannot see an object that moves

at a speed greater than the speed of light in a vacuum. Therefore, beyond the above indicated ball, we do not see a star. And they exist. But, for us, they will move at speeds greater than the speed of light. Therefore, we do not see them. If we take the escape velocity of such a ball equal to the speed of light, then we can get the mass of the visible part of the Universe, which corresponds to modern data M = 8.825 * 10^52 kg.

The Hubble-Lemetre law, that is, the movement of galaxies is not correctly regarded as confirmation of the expansion of the Universe. The motion of galaxies is the usual chaotic motion of particles, similar to Brownian motion. But, there are small clarifications. The galaxies during the collision will mainly pass through each other, or merge into a single galaxy. Therefore, after a while, from a fixed position, we will see the scattering of galaxies. That is, the scattering of galaxies is a simple consequence of the chaotic motion of galaxies in the Universe. Further, at a great distance, when the galaxies begin to interact differently (due to the large distance), gravity will begin to accelerate galaxies, as galaxies begin to repel. And therefore, we will see the already familiar picture of the scattering of galaxies, moreover, with acceleration. But, and that's not all. Since the galaxies are removed, the light emitted by the stars (galaxies) will be registered by us less intense than it was emitted (due to redshift). And the further the stars (galaxies) are from us, the more significant the effect will be. Therefore, as galaxies move away from us, the intensity of their stars will decrease. Therefore, it is impossible to see the solid disk of the Sun.

Note that the removal of galaxies is actually an experimental fact. But, this does not mean that the Universe is expanding. The movement of galaxies is an ordinary chaotic movement on a cosmic scale. One explanation for the scatter of galaxies is the work of gravitational forces at such gigantic distances. This explanation is much more logical than the concept of "expansion of the Universe". Moreover, we know exactly how gravity works within the system Earth – Moon [7, experimental verification of the law of gravity]. Already on the outskirts of our solar system, effects appear that cannot be explained by the classical law of gravity [8, Pioneer effect]. Therefore, it is logical that the work of gravitational forces between galaxies can be other. And it is likely that galaxies at a certain distance begin to repel each other, which we observe.

It is also necessary to take into account that when explaining the photometric paradox, it is intuitively accepted that the horizon of the visible Universe is infinite. This is not true. Here is a complete analogy with the human horizon of visibility: theoretically, when a person looks ahead (say, vision permits), he should see thousands and millions of kilometers... But, due to the curvature of the Earth, our horizon of visibility is only a few kilometers. Similarly, on a cosmic scale: there is a horizon of the "visible Universe", and it is due to the finiteness of the speed of light. Or we can

say it another way: if we assume that our space has a curvature other than zero, then further, everything is like on Earth, we will get a certain horizon of visibility of the Universe. And if there is a finite horizon of visibility of the Universe, for any reason, then the Olbers' paradox does not take place.

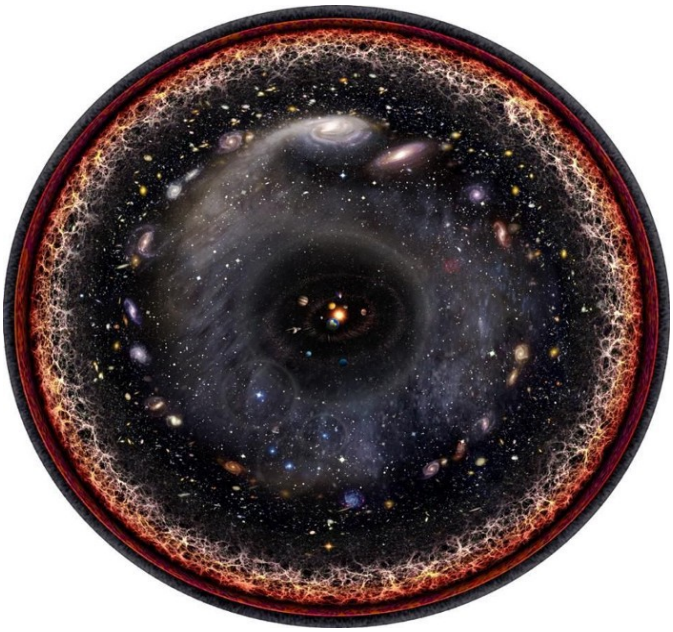
Bentley's paradox.

Bentley's paradox is a cosmological paradox: if all the stars are drawn to each other by gravitation, they should collapse into a single point [9]. The formulation of this paradox given by Bentley [10] expresses the simple idea that in the Newtonian Universe all matter will gather into one super ball. If God constantly intervenes, as Newton suggested, then the formation of such a ball will no longer be possible. In such an infinite Universe with God, the super ball will no longer exist, but the gravitational potential at each point will be infinitely large. And even God cannot fix it. God does not violate the laws of nature, he creates them, as a programmer. Thus, we logically arrived at the gravitational paradox, or the Neumann-Seeliger paradox, which is formulated as follows [11, the Russian Wikipedia Bentley's paradox]:

"In an infinite Universe with Euclidean geometry and nonzero average density of matter, the gravitational potential everywhere takes on an infinite value".

The paradox is named after the scientists C. Neumann [12] and H. Seeliger [13], who first formulated it. The gravitational paradox turned out to be a serious embarrassment to Newton's theory of gravitation, and was the fact that led scientists to believe that the classical theory of gravitation is not suitable for solving cosmological problems. But, as we will see below, this is not so: this paradox can be strictly explained only by Newtonian gravity and the limiting speed of light in vacuum. It's enough. So let's take a look.

Since the speed of light is ultimate, we will always see a limited part of the Universe. This strictly follows from the fact that galaxies acquire more and more speed as they move away from us (the Hubble-Lemetre law). Thus, at some distance from us, galaxies will have a speed equal to the speed of light. This will be the border of our visible part of the Universe (our ball). There is the Universe beyond this border, but it is invisible to us, since we cannot see an object moving at a speed greater than the speed of light in a vacuum. Therefore, behind the above ball, we will not see any matter (galaxies, stars, dust, etc.). Naturally, matter exists outside the sphere, but for us, no matter outside the sphere exists. And for the laws of nature as well! Recall that we are in the center of the ball. Look at the picture of this cosmological ball [14, Artist’s logarithmic scale conception of the observable universe. (Wikipedia user Pablo Carlos Budassi)].



Moreover, and what is especially important, it can be strictly accepted that galaxies (stars, etc.) that are outside this sphere will not be able to gravitationally interact with the center of the sphere. Otherwise, we could in a certain way experimentally fix the speed of galaxies greater than the speed of light in vacuum. This is impossible. Therefore, for the center of such a ball, the space-time continuum will be formed by all galaxies (all matter) inside the ball. And all galaxies outside the sphere will not be able to interact (or influence) the center of the sphere. That is, in our Universe (in our ball) there is only a finite amount of matter (this hypothesis was considered by Isaac Newton in a letter to Richard Bentley). It is also unforgettable that the Universe is isotropic and homogeneous. In fact, we have come to a solution to the gravitational paradox, which is given by Einstein's general relativity: the gravitational force is a local consequence of the non-Euclidean metric of space-time, and therefore the force is always uniquely determined and finite.

This follows from the fact that if we are inside such a cosmological ball, then it is quite obvious that the gravitational force at the center of the ball will be equal to zero (the Universe is isotropic and homogeneous), since the spherically symmetric distribution of matter does not create any gravitational field inside the spherical cavity. If we are in the center of such a ball, and we are on planet Earth, then the gravitational force will be determined by the local mass of planet Earth. Note that the size of the planet Earth (or even the size of the solar system) can be taken as a mathematical point if we consider our cosmological ball. That is, everything is like in Einstein's general relativity. Or everything is as described in the Almagest [15, 16].

Claudius Ptolemy and other scientists were right: the Earth is in the center of the observable Universe (from our position). The history of the development of science is not without irony...

CONCLUSION.

It is interesting to note that the cosmological ball described above can be regarded as a kind of "our Multiverse" [17]. But, as the center of the ball moves in the Universe, such a Multiverse will change (some galaxies will leave, others (new) will fall into our ball). But, the radius, mass and other characteristics of "our Multiverse" will be constant. Every observer in the Universe, or each inertial frame of reference, will "create" its "own Multiverse". But, all such Multiverse will be equal, since all inertial reference frames are equal, according to the principle of relativity. Consequently, our Universe really consists of many "Multiverse". But, all such Multiverse are "born" when an observer appears in the Universe. Everything is like in quantum mechanics: each observer creates his own Multiverse.

Finally, note that using the wave-particle dualism of microparticles, we have shown that in the Universe there is a limiting speed of motion of bodies, which is equal to the speed of light in a vacuum. Proceeding only from the limit of the speed of light, we also logically explained the photometric and gravitational paradoxes.

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