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THE LIGHT FORMULA AND ITS CONSEQUENCES

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ABSTRACT

The hypothesis of the equality of the speed of light squared and the gravitational potential of the Universe is considered. This equality explains why the speed of light does not depend on an observer's motion. The physical meaning of Einstein's formula is revealed: the energy of a body at rest is enormous because it is equal to the potential energy of the body in the gravitational field created by all massive objects in the Universe. The equality of the inertial and gravitational masses is theoretically justified. It is proposed to test the new hypothesis in laboratory experiments by measuring the speed of light with high accuracy. It is proposed to solve the problem of the possible existence of black holes in a metrology laboratory.

Keywords: Black holes, speed of light, gravitational potential.

INTRODUCTION

In 1916, Albert Einstein, based on his theory of gravity, predicted the existence of gravitational waves (Einstein, 1916). Unfortunately, Einstein made a mistake in this work, which he corrected after one and half year when he wrote another article on gravitational waves (Einstein, 1918). In the second half of the 20th century many scientists tried to detect gravitational waves but without success. Finally, on September 14, 2015, LIGO Scientific Collaboration and Virgo Collaboration discovered a signal that was later interpreted as a gravitational surge from the fusion of two black holes with 29 and 36 solar masses. According to calculations, the released energy was three solar masses. The discovery was announced on February 11, 2016 (Abbott *et al*., 2016). On August 17, 2017, a signal was recorded that was interpreted as a fusion of two neutron stars (Abbott *et al*., 2017). These events solved three unresolved problems of gravitational physics at once: detection of black holes, detection of gravitational waves and measurement of the speed of gravity.

In this connection it is necessary to emphasize that, as a rule, only one unknown value is determined in a reliable experiment. Moreover, all other quantities are assumed to be well known and verified in other experiments. Therefore, the definition of three unknown quantities in one and the same experiment is in doubt about the correctness of its interpretation. To dispel these fears, the author proposes to conduct independent research on the existence of black holes and the speed of gravity propagation. In fact, until now the speed of gravity propagation has not been measured. Therefore, there are various hypotheses about this. For example, the French mathematician Pierre Laplace investigating the motion of the Moon around the Earth came to the conclusion that the gravitational interaction must be transmitted at a speed several million times faster than light. It is because the assumption of a lower velocity of gravity does not agree with the observed data (Laplace, 1846).

After constructing the theory of relativity, many scientists became skeptical about that gravity can propagate faster than light. But after constructing quantum mechanics, an unusual phenomenon called nonlocality was discovered. In some cases, quantum objects after interaction behave as a single whole and react to external interaction as a single whole. The state of one quantum object can instantly change after a measurement done on another quantum object, which can be at a great distance. In 2004, the author put forward the hypothesis that all the gravitational fields inside the Universe are united by a nonlocal connection (Yanchilin, 2004). Zakharenko has developed a dynamical model relating to the numerical experiment that allows propagations for a complicated system with the speed of light (electromagnetic and gravitational waves) and faster speeds many orders of magnitude higher than the speed of light (Zakharenko, 2016, 2017a, 2017b). And the evaluated limiting speed must be below 10^{27} m/s.

As for black holes, so far no black hole has been officially detected, despite the fact that there are a lot of candidates for black holes. Moreover, super massive objects in the centers of galaxies (Eckart and Genzel, 1996) present astronomers with surprises. For example, in the very

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center of our Galaxy there were discovered clusters of very young stars (Martins *et al*., 2008). The formation of such star clusters near the super massive black hole does not agree well with modern theories of star formation. To find out whether super massive and compact objects are black holes, it is necessary to establish the presence of events horizons near them. This is practically impossible to do, using modern technique of astronomical observations. Therefore, the question of the existence of black holes continues to remain unanswered. In this regard, the author proposes a new approach, which, perhaps, will help to give an unambiguous answer to the question of the existence of black holes. The author considers a hypothesis that can be tested experimentally under terrestrial conditions and according to which super massive objects are not black holes.

The Hypothesis of the Connection Between the Speed of Light and the Gravitational Potential

By human standards, Earth's mass is enormous. To fly out of its gravitational field, you need to develop a speed of 11.2 km/s. This is a very high speed, but it is much smaller than the speed of light. To leave the Solar System, you need to develop even greater speed. The more massive the object, the deeper its gravitational potential and the higher speed you need in order to leave its gravitational field. There is a certain hierarchy in the Universe. Stars combine into clusters. Star clusters are part of the Galaxy. Galaxies are grouped together. Groups form clusters of galaxies, which, in turn, combine into super clusters, from which a large-scale structure of the Universe is formed. As we move to larger systems, their gravitational potential increases. The gravitational potential is getting deeper and deeper, approaching a certain maximum, which corresponds to the potential of all matter in the Universe.

Using date about the size and average density of the observable Universe, we can estimate its gravitational potential. Such calculations have been made repeatedly and a very interesting result was obtained. The absolute magnitude of the gravitational potential of the Universe Φ is approximately equal to the square of the speed of light c: $|\Phi| \approx c^2$. This means that the sum of total and gravitational energies for any object is almost zero. Here is how Richard Feynman comments on this result: "With this estimate, we get the exciting result that the total energy of the universe is zero. Why this should be so is one of the great mysteries – and therefore one of the important questions of physics. After all, what would be the use of studying physics if the mysteries were not the most important things to investigate?" (Feynman *et al*., 1995).

Let's explore this mysterious coincidence of two different physical quantities. We will assume that the coincidence of the gravitational potential of the Universe and the speed of light squared is not accidental, but expresses a certain law of nature. Therefore, we postulate that the square of the speed of light c is determined by the gravitational potential of the Universe as follows (Yanchilin, 2000):

$$c^2 = -\Phi \tag{1}$$

Here Φ is the gravitational potential created by the distribution of all matter in the Universe at a given point in space. It is normalized so as to tend to zero at a great distance from all the masses of the Universe, therefore, $\Phi < 0$.

As a working hypothesis, we will consider equation (1) as a new physical law. We will look at the consequences of this assumption. Once Richard Feynman lectured on how to put forward new laws and verify their correctness. He suggested a way how to distinguish the true hypothesis from a false one. Here is what he told about this: "One of the most important things in this 'guess – compute consequences – compare with experiment' business is to know when you are right. It is possible to know when you are right way ahead of checking all the consequences. You can recognize truth by its beauty and simplicity. It is always easy when you have made a guess, and done two or three little calculations to make sure that it is not obviously wrong, to know that it is right. When you get it right, it is obvious that it is right – at least if you have any experience – because usually what happens is that more comes out than goes in. Your guess is, in fact, that something is very simple. If you cannot see immediately that it is wrong, and it is simpler than it was before, then it is right" (Feynman, 1985) From Feynman's words, we can conclude that if we put forward a simple hypothesis and if after two or three little calculations did not come to a contradiction, then our hypothesis is correct.

Let's investigate the consequences that follow from equation (1), and if this equation is incorrect, then we must come to a contradiction.

Theory of Relativity and Einstein's Formula

The depth of the gravitational potential of the Universe at different points in space can be different. In this case, as follows from equation (1), the speed of light will also be different at different points of space. For example, near a large mass, the depth of the gravitational potential increases, and the speed of light must increase.

Consequently, the light will be accelerated in a gravitational field. Let's see if such an assumption contradicts the theory of relativity. According to the theory of relativity, the magnitude of the speed of light does not depend on the motion of the light source and does not depend on an observer's motion. We can move at any speed towards the light or, conversely, in the opposite direction, in any case the light will sweep past us with the same speed 300,000 km/s. Albert Einstein explained this paradox as follows: the time and length scale in a moving reference system vary in such a way that the light moves relative to it at a speed of 300,000 km/s.

Thus, the theory of relativity asserts that the magnitude of the speed of light does not depend on the motion of the light source and on the motion of an observer. But this theory does not prohibit the speed of light to be different in different points of space. Moreover, equation (1) explains the basic postulate of the theory of relativity. Indeed, if the speed of light depends only on the magnitude of the gravitational potential, then it should not depend on an observer's motion, because the gravitational potential does not depend on an observer's motion.

Equation (1) allows us to take a fresh look at Einstein's famous formula, which connects mass and energy. According to Einstein's formula, any mass m has an energy E and the following equality holds (Einstein, 1905):

$$E = mc^2 \tag{2}$$

Thus, anybody has a tremendous energy. For example, the energy of mass of 1 kg is almost 10^{17} joules. Why does the mass have such tremendous energy? The theory of relativity does not answer this question. Let's multiply equation (1) by the mass m:

$$mc^2 = -m\Phi \tag{3}$$

We have obtained that the energy of any body is exactly equal to its potential energy with a minus sign in the gravitational field of the Universe. From a new point of view, a body has energy because it is in a gravitational interaction with the rest of the matter in the Universe. The energy of a body is enormous, because the total mass of the Universe is huge.

Equality of the Inertial and Gravitational Masses

In physics, the inertial mass and the gravitational mass are different values. The inertial mass exerts resistance to acceleration (it is in Newton's Second Law). The gravitational mass participates in gravitational interaction (it is in the law of universal gravitation). Thanks to numerous experiments it is known that the inertial mass of a body is always equal to its gravitational mass. Einstein used this equality when constructing the general relativity. It must be emphasized that the equality of these masses has no explanation. Richard Feynman calls this equality the first amazing fact associated with gravity (Feynman *et al*., 1995).

Suppose that we do not know about experiments that prove the fact of equality of the inertial and gravitational masses. Could we in this case prove the fact of this equality, relying on the new equation (1)? Let's try to do it. According to Einstein's formula, the energy of a body depends on its inert mass m_{in} and therefore, we should write the equation (1) in this form:

$$E = m_{in}c^2 \tag{4}$$

The formula for potential energy includes the gravitational mass of a body m_{gr}. So, the potential energy of the body U in the gravitational field of the Universe is:

$$U = m_{gr}\Phi \tag{5}$$

The potential energy of a body is negative: $U < 0$. Which value is larger in modulus: E or U? Let's try to answer this question, relying on equation (1). It follows from this equation that no one body can leave the Universe, because even light, moving away from all the stars and galaxies, will stop. Hence: $E \le |U|$. On the other hand, if the body is turned into light as a result of annihilation, then this light will reach the edge of the Universe, where the gravitational potential of the Universe tends to zero. Thus, all the energy of the body is enough to reach the border of the Universe. We can conclude:

$$E + U = 0 \tag{6}$$

Taking into account equations (4) and (5), we obtain:

$$m_{in}c^2 + m_{gr}\Phi = 0 \tag{7}$$

Substituting the speed of light from equation (1) into equation (7) and reducing, we get:

$$m_{in} = m_{gr} \tag{8}$$

Thus, using the new physical law (1), we were able to theoretically substantiate the equality of the inertial and gravitational masses (8), which was experimentally verified with very high accuracy but had no theoretical basis. The essence of this rationale is simple. Anybody has an energy only because it is in a gravitational interaction with the rest of the bodies of the Universe. Therefore, the total energy of the body is equal to its potential energy with a minus sign. On the one hand, the total energy of the body is equal to its inert mass multiplied by the speed of light squared. On the other hand, the potential energy of the body is equal to its gravitational mass multiplied by the gravitational potential of the Universe. If the gravitational potential is equal to the speed of light squared (1), then the inertial and gravitational masses of anybody are equal.

Gravitational Mass in a Gravitational Field

An infinitesimal work *dA* done above a body for its infinitesimal displacement in a gravitational field equals:

$$dA = -m_{gr} d\Phi \tag{9}$$

$d\Phi$ is an infinitesimal change in the gravitational potential. We can conclude from the law of conservation of energy, that a complete change in the energy of a body *dE*, including its rest energy, is equal to the work done above it: $dE = dA$. Using Einstein's formula (4), we can conclude:

$$dA = dE = d(m_{in}c^2) \tag{10}$$

We take the differential of the right-hand side of the equation:

$$dA = dE = d(m_{in}c^2) = m_{in}dc^2 + c^2 dm_{in} \tag{11}$$

Let us look closely at equation (11). This is the usual law of conservation of energy. When the work is done above the body, then its total energy increases. The total energy of the body depends only on two quantities: its inertial mass and the speed of light. If we assume that the speed of light does not change: $dc = 0$, then the first term on the right-hand side of equation (11) becomes zero, and we get:

$$dA = dE = d(m_{in}c^2) = c^2 dm_{in} \tag{12}$$

The essence of this equation is that the inertial mass of a body increases with its energy. If we give the body energy, then together with energy we will give the body an inert mass. Therefore, when the body accelerates, its inert mass increases. This fact is well known and frequently verified while accelerating elementary particles at colliders and other accelerators.

At the beginning of the 20th century, some physicists, for instance, Nordström (1913a,b) tried to construct a new theory of gravitation on the basis of the theory of relativity. They had great difficulties because of equation (12) and equation (8). After all, the gravitational mass of a body shows how strongly this body participates in the gravitational interaction and thus plays the role of the gravitational charge of the body. But if the body accelerates in a gravitational field, then its inert mass increases with energy, and, consequently, the gravitational mass must increase. Let us imagine a system consisting of several stars. Consider one star that accelerates under the influence of the gravity of other stars. In this case, its inertial and gravitational masses increase. If the gravitational mass has grown, then immediately the potential energy of all other stars of this system should change. Serious problems arise due to the fact that the gravitational mass changes. Therefore, Einstein abandoned the construction of the scalar theory of gravitation and proceeded to construct the tensor theory of gravitation (general relativity). Similar problems would arise in electrodynamics if the magnitude of the electric charge depended on its velocity.

Let us return to equation (11). Let us combine this equation with equation (9):

$$-m_{gr} d\Phi = m_{in}dc^2 + c^2 dm_{in} \tag{13}$$

Instead of the gravitational potential, we substitute the speed of light *c* from equation (1):

$$m_{gr} dc^2 = m_{in}dc^2 + c^2 dm_{in} \tag{14}$$

Taking into account the equality of the inertial and gravitational masses, we obtain $c^2 dm_{in} = 0$, or:

$$m_{in} = \text{const} \tag{15}$$

Using the light formula (1), we obtained a very interesting result. When a body accelerates in a gravitational field, the body energy increases and the inertial mass remains constant. Why is this happening? It is because the speed of light increases. The growth of the speed of light is exactly such as to ensure the growth of the total energy with a constant inert mass. Since the inertial and gravitational masses are equal, the gravitational mass of a body remains constant when it moves in a gravitational field. In this case, the gravitational mass of the body, playing the role of the gravitational charge of this body, does not change under gravitational interaction. Equation (15) can be expressed in terms of the total energy of the body *E* (Yanchilin, 2003):

$$\frac{E}{c^2} = \text{const} \tag{16}$$

When moving any object (ordinary body, electromagnetic wave, electron...) in a gravitational field, the ratio of its total energy to the speed of light squared is preserved.

Black Holes and the Light Formula

The French mathematician Pierre Laplace was one of the first who put forward a hypothesis about the possible existence of dark stars (the term "black hole" was introduced in the second half of the twentieth century). Using Newton's law of gravitation he calculated a star's mass, for which the escape velocity is equal to the speed of light. Here is the formula for the escape speed V, which is now known to university students:

$$V^2 = 2\frac{GM}{R} \tag{17}$$

M is a star's mass, R is its radius, and G is the gravitational constant. If we substitute the speed of light c into equation (17), we will obtain the well-known formula for the gravitational radius r_g of a black hole:

$$r_g = \frac{2GM}{c^2} \tag{18}$$

Thus, within the framework of Newton's gravitation theory, massive objects can exist, from the surface of which even light cannot escape.

According to general relativity, such objects can also exist. Their gravitational radius r_g coincides with the radius (18), calculated within the framework of Newton's theory. But it must be emphasized that a black hole in general relativity is fundamentally different from a black hole in Newtonian theory. According to the general relativity, time slows down more and more while approaching the gravitational radius, and as a result, stops completely. Time becomes imaginary within the gravity radius. The force of gravitational attraction, acting from a black hole to a test body, increases as the body approaches the gravitational radius right up to infinity (Thorne, 1986). An observer free falling into a black hole reaches the gravitational radius and penetrates it in finite time on his watch. But for an observer located at a great distance from the black hole, falling observer never gets inside the gravitational radius, since he would need infinite time only in order to reach the gravitational radius. A black hole is not like a real physical object.

Many famous scientists did not believe in the existence of black holes. For example, in 1939 Albert Einstein wrote an article, the main result of which was the proof that black holes should not exist in the real world (Einstein, 1939). It turns out that Einstein did not believe and did not even allow the possibility of the existence in nature of black holes that follow from his theory. Richard Feynman was negative about the fact that within a black hole the square of time becomes negative. In his lectures on gravitation, he even discussed the possibility of improving general relativity in order to avoid such difficulties (Feynman *et al*., 1995). The famous specialist in general relativity Möller also was negative about the existence of black holes. He concluded that Einstein's theory of gravity is not true in strong fields, because the existence of black holes follows from it (Möller, 1979). Even such a supporter of general relativity as Nobel laureate Steven Weinberg believed that black holes are not relevant to the real world (Weinberg, 1972).

The reaction of the active supporter of the general relativity of Arthur Eddington is indicative. In January 1934, at a meeting of the Royal Society of England, a young Indian scientist Chandrasekhar made a report on the existence of the limiting mass for a white dwarf. Relying on the general relativity, Chandrasekhar concluded that a sufficiently massive star must collapse to the point. When Eddington heard this, he declared that there must be a law of nature that would not allow such absurd behavior of the star (Thorne, 1994).

Why does the possibility of black holes appear in Newton's theory of gravity and Einstein's theory of gravity? It is because the total energy of any body, in spite of the fact that it is very large, is still not infinite (2). If a body is near a very massive object, then all the energy of this body is not enough to overcome its gravitational attraction.

According to equation (1), the problem changes radically. From a new point of view, anybody has energy only because it is surrounded by other bodies of the Universe (6). The deeper a body is in a gravitational field, the more its internal energy. The total energy of the body is exactly equal to its gravitational energy of attraction to all other bodies of the Universe. Therefore, it is always greater than the energy of attraction to a single body.

Let's consider as an example a huge massive object on the surface of which the gravitational potential is equal to Φ_M, and the potential is equal to Φ at a great distance from it. Under what condition can a photon overcome the attraction field of this object?

A photon has the energy ε. That means that it has an inertial and gravitational mass which is equal to ε/c^2. In order for the photon to fly out of the region with the potential Φ_M and get into the region with the potential Φ, it needs to do work A:

$$A = \frac{\varepsilon}{c^2}(\Phi - \Phi_M) \qquad (19)$$

Suppose the speed of light is constant. In this case, it is clear from equation (19) that for a large value of the difference of the gravitational potentials, the work *A* can be larger than the photon energy ε. In this case, the photon cannot leave the gravitational field. From a new point of view, the difference of gravitational potentials is always less than the square of the speed of light. It is because the square of the speed of light increases near a massive object. Therefore, the energy of the photon is always greater than the work necessary to overcome the field of attraction, and therefore the photon can fly out of any gravitational field. If equation (1) is true, then black holes do not exist. The correctness of equation (1) can be verified experimentally, measuring with high accuracy how the speed of light depends on the altitude above the Earth's surface. If it turns out that the speed of light decreases with altitude, this will mean that compact and massive objects in the centers of galaxies are not black holes. This, in turn, will change our perception of the processes taking place in space.

CONCLUSION

We investigated the mysterious equality of the speed of light squared and the gravitational potential of the Universe. We put forward the hypothesis that the speed of light squared is determined by the gravitational potential of the Universe (1), and that's why these quantities are always equal. As it turned out, the new hypothesis clarifies the physical meaning of Einstein's famous formula connecting mass and energy. We found out that anybody has energy only because it is in a gravitational interaction with the rest of the objects of the Universe. The energy of a body at rest is enormous, because the gravitational potential of the Universe is huge. Using a new hypothesis, we were able to theoretically justify that the gravitational mass of a body is always equal to its inertial mass. This equation has been verified with high accuracy in numerous experiments, but so far it had no theoretical justification. From the light formula (1) it follows that the speed of light decreases with altitude above the Earth's surface. As it is not difficult to estimate, this effect has a relative order of magnitude of 10^{-16} for each meter of ascent. The author hopes to attract experts in the field of metrology with this publication, so that they can experimentally find out whether this is true or not. If it turns out that the speed of light decreases with altitude, it will mean that the super massive objects in the centers of galaxies are not black holes within the framework of general relativity. This will radically change our understanding of the physical processes taking place in galaxies and the role of galactic nuclei.

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