BUILDING A PHYSICAL AND MATHEMATICAL MODEL OF THE GRAVITATIONAL FIELD

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Abstract: *the problem of gravitational field physics is to identify the relationship between the gravitational field and the expansion of the space-time continuum. Therefore, it is also important to create models, the study of which allows you to identify these relationships and Express them with formulas. In this article, the gravitational field of a stationary centrally symmetric object is studied using a simplified model of the coordinate system and the maximum distance of capture of a test particle by the gravitational field is calculated. A model of the gravitational field is presented that combines quantum properties with the expansion of the space-time continuum.*
Keywords: *Hubble Constant, gravitational field, quantum properties*.

ПОСТРОЕНИЕ ФИЗИКО-МАТЕМАТИЧЕСКОЙ МОДЕЛИ ГРАВИТАЦИОННОГО ПОЛЯ

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Аннотация: *проблемой физики гравитационного поля является выявление взаимосвязи гравитационного поля и расширения пространственно-временного континуума. Поэтому актуально и создание моделей, исследование которых позволяет выявить эти взаимосвязи и выразить их формулами. В данной статье на упрощённой модели системы координат исследовано гравитационное поле стационарного центрально-симметричного объекта и рассчитано предельное расстояние захвата пробной частицы гравитационным полем. Представлена модель гравитационного поля, объединяющая квантовые свойства с расширением пространственно-временного континуума.*
Ключевые слова: *постоянная Хаббла, гравитационное поле, квантовые свойства.*

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Introduction: Modeling in physics serves as a method of scientific knowledge. Visual models are widely used in scientific and theoretical research. These include hypotheses, analogies, diagrams, graphs, and diagrams.

Relevance: The problem of gravitational field physics is to identify the relationship between the gravitational field and the expansion of the space-time continuum. Therefore, it is also important to create models, the study of which allows you to identify these relationships and express them with formulas. In modern theories of the gravitational field, small quantities appear, which are neglected when deriving formulas of practical application. An urgent task of physics is to create models that can be used to analyze these small quantities.

Goals: identify the relationship between the gravitational field and the expansion of the space-time continuum by modeling and Express it with physical formulas.

Task: mathematical calculation of models and output of physical formulas.

Scientific novelty: Hubble's law, which describes the expansion of the vacuum, is established when observing galaxies and is used for research in astrophysics. When calculating the gravitational field of compact objects, the Hubble law is not taken into account because of the negligible manifestation at close distances by cosmic standards. The novelty of the research results lies in the fact that the method of modeling revealed a way to make corrections to the calculations of the gravitational field, taking into account the manifestation of the Hubble law. At the same time, it was found that the established formulas correspond to the physics of elementary particles.

Results: created model of the gravitational field, which takes into account the Hubble constant as a parameter; using the formula for marginal distances of the capture of the test particle mass gravitational field; refined formula of a Schwarzschild black hole; the regularities of quantum quantities in elementary particle physics.

1. Analyzing the spectra of galaxies, Edwin Hubble came to the conclusion that most galaxies are moving away from us at speeds proportional to the distance to them. Galaxies are moving away not only from our Galaxy, but also from each other. The picture of the expansion of the Universe associated with Hubble's law appears to be the same for an observer located at any point in space [1].

A fundamental observational fact is that the absorption lines in the spectra of nearby galaxies are shifted to the red side of the spectrum. There are two types of redshift known: Doppler and gravitational. In the 20s of the last century, the General theory of relativity was not yet as widely known and familiar as it is now. Therefore, it is quite natural that observers interpreted the red shift in the spectra of galaxies as Doppler. However, in modern cosmological theories, the expansion of the Universe is related to the curvature of the space-time continuum, which is equivalent to the gravitational field. Any theory that fulfills the principle of equivalence of inertial and gravitational masses and the local law of conservation of energy must give a correct description of the gravitational frequency shift [2].

2. In an expanding space-time continuum, the test particle moves relative to the observer with acceleration directed away from the observation point:

$$a = c \cdot H \qquad (1)$$

c – speed of light, H – Hubble constant.

The speed of the test particle, estimated by an observer from a distance L:

$$u = at = cHt \qquad (2)$$

here t - time it takes for the light from the particle to reach the observation point.

$$t = \frac{L}{c} \qquad (3)$$

Substituting (3) in (2), we get the formula of Hubble's law:

$$u = H \cdot L \qquad (4)$$

here L – distance from the test particle to the observer.

The gravitational field is characterized by a potential, which is related to the tension by the ratio:

$$\partial\varphi = -g\frac{\partial r}{c^2} \qquad (5)$$

For the model under consideration, following the principle of equivalence of acceleration and gravitational field strength, we can write:

$$\partial\varphi = -H\frac{\partial r}{c} \qquad (6)$$

After integrating from 0 to L, we have:

$$(1 + \varphi) = \left(1 - \frac{HL}{c}\right) \qquad (7)$$

Doppler and gravitational redshifts are equivalent in the derivation of Hubble's law and are described by the equation:

$$f = \left(1 - \frac{HL}{c}\right) f_0 \qquad (8)$$

here f_0 - frequency of light emitted by the observed object; f - frequency of light reaching the observer.

Thus, the model of gravitational redshift is consistent with the theory of expansion of the space-time continuum.

3. Let's determine the distance from a centrally symmetric compact object of mass M, at which the gravitational field of the object and the vacuum are equal in magnitude and opposite in direction:

$$\frac{GM}{R^2} = c \cdot H \qquad (9)$$

From equation (9) we find:

$$R = \left(\frac{GM}{cH}\right)^{\frac{1}{2}} \qquad (10)$$

R- limit distance of capture by the gravitational field of the test particle. At a distance greater than R, the test particle will move away from the gravitational mass.

4. Consider the problem of the maximum capture distance in the Solar system:

The mass of the Sun is $1.989 \cdot 10^{30}$ kg. Calculating the maximum distance at which a cosmic body will be captured by the attraction of the Sun gives the result $3.6 \cdot 10^{11}$ km.

The distance from the Sun to the comet belt "Oort cloud" on the outskirts of the Solar system has a length of $1.5 * 10^{10}$ to $2.25 * 10^{10}$ km. Some comets are even farther away from the peripheral regions of the Oort cloud, but we must also take into account the contribution of giant planets, the Kuiper asteroid belt, and the comet belt to the creation of a gravitational field on the outskirts of the Solar system and the corresponding local increase in the capture distance.

Thus, the size of the Solar system corresponds to and is determined by the value of the maximum capture radius [3].

5. We investigate at what value of the limiting capture radius r0 the mass of the microparticle is the value:

$$m = \frac{h\omega}{c^2} = \frac{h}{c \cdot r_0} \qquad (11)$$

Substituting (11) into (10), after algebraic transformations, we have:

$$r_0 = \left(\frac{Gh}{Hc^2}\right)^{\frac{1}{3}} \qquad (12)$$

The classical electron radius is determined by the formula (12).

6. We investigate what will be the value of the maximum capture radius for the Planck mass:

$$m_P = \left(\frac{hc}{G}\right)^{\frac{1}{2}} = \frac{h\omega_P}{c^2} \qquad (13)$$

Substituting the mass value (13) in the formula (10) and after algebraic transformations we get:

$$R = \frac{c}{(H\omega_P)^{\frac{1}{2}}} \qquad (14)$$

7. We study the process of accretion of a sample mass particle to a compact object with a mass of M.

Let the particle and the compact object be on the Or coordinate axis, with the origin coinciding with the object. Then the increment of the particle velocity is determined by the equation:

$$\partial v = \left(\frac{GM}{r^2} - cH\right) \partial t \qquad (15)$$

In equation (15) we substitute the relation $\partial t = \partial r / v$ and after algebraic transformations we integrate within the range of

$\left(-\left(\frac{GM}{cH}\right)^{\frac{1}{2}}\right)$ до (-r).

We have: $v^2 = \frac{2GM}{r} + 2cHr - 4(GMcH)^{\frac{1}{2}}$ (16)

For the case when the velocity v approaches the speed of light in a vacuum, and the accreting particle approaches the event horizon of a black hole with radius R, we obtain the quadratic equation from equation (16):

$$R^2 - \left[\frac{c}{2H} + 2\left(\frac{GM}{cH}\right)^{\frac{1}{2}}\right]R + \frac{GM}{cH} = 0 \qquad (17)$$

We solve the quadratic equation (17) and decompose the radical function (in the solution) into a power series. This is acceptable if the maximum capture radius is much less than c/H.

For the first four terms of the Taylor series, we obtain an equation from which, after transformations, we derive the formula for the event horizon of a black hole:

$$R = \frac{2GM}{c^2} - \frac{8GM}{c^2} \cdot \left(\frac{GMH}{c^3}\right)^{\frac{1}{2}} \qquad (18)$$

The resulting radius of the event horizon of the black hole is less than the radius of the Schwarzschild black hole [1] by:

$$\Delta R = 4R \cdot \left(\frac{RH}{2c}\right)^{\frac{1}{2}} \qquad (19)$$

This value ΔR corresponds to the mass defect:

$$\Delta M = 4M\left(\frac{GMH}{c^3}\right)^{\frac{1}{2}} \qquad (20)$$

To evaluate the significance of formulas (19) and (20), we consider the following examples.

8. Hawking's black hole theorem: "For any interaction, the surface area of a black hole can never decrease. If there are multiple black holes, the sum of their surface areas can also never decrease. That is, the area of the event horizon of a black hole behaves like entropy" [4]. However, the mass defect expressed by formula (20) compensates for the "entropy" when black holes merge. After all, for example, when two identical black holes merge, the mass defect will increase by 1.4 times, in accordance with the formula (20). The need for calculations and clarifications is obvious.

9. We determine the mass defect for a black hole with an event horizon radius equal to the classical electron radius. From formulas (12), (19), (20) we get after algebraic transformations:

$$\Delta m = 1{,}4m_P \qquad (21)$$

Conclusion:

The use of the Hubble constant as a parameter in theoretical studies of the gravitational field is promising. Calculations made without neglecting small quantities give interesting results: the limit radius of capture by the gravitational field of a test particle of mass; the Schwarzschild formula for the mass defect of a black hole; relations expressing the dependence of quantum physics quantities on the Hubble constant [5].

References / Список литературы

1. *Berke W.* Space-time, geometry, cosmology. Per. s Engl. M.: Mir, 1985. 416 s., ill.
2. *Orer G.* Physics. Full course. M.: Mir, 2010. 752 p.
3. *Weinberg S.* Cosmology. M.: URSS, 2013. 608 p.
4. *Shapiro S., Teukolsky S.* Black holes, white dwarfs and neutron stars. Part 2. M.: Mir, 1985. 300 p.
5. *Kassenova L.G., Zhanbusinova B.H.* What do we know about the gravitational constant G? // Vestnik nauki i obrazovaniya. Chast'1. [Bulletin of science and education. Part 1]. 2020. № 17 (95). Pp. 5-7.