NEW PHYSICAL-MATHEMATICAL SUBSTANTIATION OF ENERGY AND FORCE PARAMETERS OF THE EARTH'S GRAVITATIONAL FIELD

Abstract. The work relates to the field of research of gravitational fields, in particular, their wave, energy and force parameters for planetary level objects. Based on the analysis of the problems of their determination for the Earth, it is shown that the relationship of these parameters does not have an explicit form, which complicates the task of their determination. The solution of this problem is the main goal of the work performed, and its scientific novelty is a new principle of substantiation of the action of gravitational forces. The research methods used in the work are based on deduction and induction, the general principles of the theory of knowledge and the application of reliable laws of physics. Work results. A fundamentally new approach is proposed, on the basis of which new calculated dependences and their numerical values were found for the first time to determine the action of the forces of gravity of planetary systems. They are confirmed by comparative calculations of the new gravitational parameters of the Earth, which agree well with its known parameters. Conclusions. For the first time, new scientific data have been obtained, which significantly expand the range of parameters of the gravitational field of the planets and the level of knowledge of the fundamentals of the material world.

Keywords: wave parameters of the gravitational field, energy and force of gravity at the planetary level.

Introduction. The work relates to the field of study of the main physical fields, in particular, to the wave, energy and force parameters of the gravitational field of the Universe and its constituent cosmic objects of the planetary level. Despite the importance of these problems for understanding the foundations of the material world, the gravitational field and its parameters are still poorly understood. This is explained by the fact that the scientific substantiation of the principles of action and the laws of the formation of gravity and the gravitational field of the Universe, and
the cosmic objects included in it, is a complex scientific problem, the solution of which is devoted to a large number of scientific works. They are based on Newton's work [1], in which the gravitational force \( F_G \) of 2-point bodies with masses \( m_1 \) and \( m_2 \) located at a distance \( r \) between them was first substantiated. Currently, this force is expressed by Newton's law (1) of universal gravitation [2]:

\[
F_G = G \frac{m_1 m_2}{r^2} \ (N),
\]

(1)

Where \( G \) is the gravitational constant, the value (2) of which is currently recommended by CODATA [3]:

\[
G = 6.67408(31) \times 10^{-11} \ \frac{m^3}{kg \cdot s^2};
\]

(2)

Until the beginning of the 20th century, dependence (1) was the only one that strictly allowed one to determine the numerical parameters of the gravitational action. However, in the 20th century, Einstein's work on the general theory of relativity (GR) [4] was taken as the basis for the theory of gravity. At the same time, the action of gravitational forces was replaced by a transition from the structure of the physical field to the mathematical curvature of space. This pushed the study of not mathematical, but physical principles of operation and the laws of gravity, to the background of the problems of the material world.

However, in the 21st century, new scientific information about the gravitational field has appeared which is substantiated experimentally and theoretically. In particular, these include:

1) The discovery of gravitational waves, the registration of which was made in the LIGO laboratories and was awarded the Nobel Prize in Physics in 2017 [5], [6].

2) Justification on strict scientific principles of the wave parameters of the gravitational field [7] – [10].

3) Justification on strict scientific principles of the force parameters of the gravitational field [11], [12].

Thus, the further task of the work performed is the analysis of the known wave and force parameters of the gravitational field and their justification for use in planetary level systems.
Analysis of the state of the problem, the choice of goals and objectives of the work. It should be noted that the LIGO laboratories [5], [6] recorded only the presence of gravitational field waves, which made them and the wave structure of this field a reliably established scientific fact. However type and the numerical values of these wave parameters were not determined. To determine them, in the work performed a new principle for solving scientific problems was adopted as the basic one, with the transition to the quantum-mechanical (initial) level of the material world (Nastasenko level), which was justified in [13]. The main feature of this level is the possibility of forming all physical values known in the material world, and their numerical parameters, based on 6 fundamental physical constants [13]. Numerical values of these constants are presented in [3]:

1. Speed of light in vacuum $c$:

$$c = 0.299792458 \cdot 10^9 \left( \frac{m}{s} \right).$$  \hspace{1cm} (3)

2. Planck's constant $h$:

$$h = 6.626070040 \cdot 10^{-34} \left( \frac{kg \cdot m^2}{s} \right).$$ \hspace{1cm} (4)

3. Gravitational constant $G$ (2).

4. Electrical constant

$$\varepsilon_0 = 8.854187817 \cdot 10^{-12} \left( \frac{A^2 \cdot s^4}{kg \cdot m^3} \right).$$

5. Magnetic constant

$$\mu_0 = \frac{1}{\varepsilon_0 c^2} = 4 \pi \cdot 10^{-7} \left( \frac{N}{A^2} \right).$$

6. Thermal constant Vine $b = 2.897756 \times 10^{-3} (m \cdot K)$. The advantage of this method is that it makes it possible to find not only strict physical dependences of the sought quantities, but also their real numerical values.

The main wave parameters of the gravitational field and their numerical values were first determined in [7], [8] and further developed in [9] – [10]. They are:

Frequency of oscillation wave of gravitational field $\nu_G$, are determined by strict physical dependence as shown in formula (5) obtained on the basis of Planck’s values $\nu_P$. She used strict physical regularities, consisting of 3 initial fundamental
physical constants [2], the gravitational constant \( G \) (2), the speed \( c \) of light in vacuum (3), Planck’s constant \( h \) (4):

\[
V_G = V_p = \frac{c}{\sqrt{Gh}} = \frac{0.299792458 \cdot 10^9 \left( \frac{m}{s} \right)^5}{6.67408 \cdot 10^{-11} \left( \frac{m^3}{kg \cdot s^2} \right) \cdot 6.62607004 \cdot 10^{-34} (J \cdot s)} = 7.39994 \cdot 10^{42} (s^{-1}).
\] (5)

Depending (5) used strict physical regularities, consisting of 3 initial fundamental physical constants. Therefore, \( v_G \) is a constant of the same level of significance, and its negation is equivalent to the negation of the constants \( c, h, G \). Further in text: \( v_G \) is Nastasenko's quantum frequency constant, which was obtained in [7] on the basis of a general refinement of dependence (5) for the current values of the constants \( c, h, G \) over the past years of their study.

\[
v_G = 7.39994 \cdot 10^{42} (s^{-1}) \rightarrow 7.4 \cdot 10^{42} (s^{-1}).
\] (6)

Its frequency \( v_G \) refers to the radial parameter of gravitational waves.

On the basis frequency of oscillation wave of the gravitational field \( v_G = v_p \) in [8] – [10] which made it possible to obtain its other wave parameters the gravitational fields at the strict physical level (7) … (11). His equivalents of Planck’s values of length \( l_p \) (8), time \( t_p \) (7), mass \( m_p \) (11) and energy \( E_p \) (10), obtained on the basis of strict physical regularities, consisting of 3 initial fundamental physical constants \( G \) (2), \( c \) (4) and \( h \) (5).

Period of oscillation \( T_G \):

\[
T_G = \frac{1}{V_G} = \frac{1}{7.4 \cdot 10^{-42} (s^{-1})} = 0.135136 \cdot 10^{-42} (s) = t_p = \frac{\hbar G}{c^5} = 0.135136 \cdot 10^{-42} (s),
\] (7)

Length of carrier wave \( \lambda_G \):

\[
\lambda_G = \frac{c}{V_G} = \frac{0.299792458 \cdot 10^9 \left( \frac{m}{s} \right)}{7.4 \cdot 10^{42} (s^{-1})} = 4.051249 \cdot 432 \cdot 10^{-35} (m) = l_p = \frac{\hbar G}{c^3} = 4.05126 \cdot 10^{-35} (m),
\] (8)

Amplitude of oscillation \( A_G \):

\[
A_G = \lambda_G = 4.051249 \cdot 432 \cdot 10^{-35} (m) = l_p = \frac{\hbar G}{c^3} = 4.05126 \cdot 10^{-35} (m).
\] (9)
Wave energy $E_G$, its maximum quantum of energy:

$$E_G = \hbar \nu_G = 6.626070040 \cdot 10^{-34} \text{(J \cdot s)} \cdot 7.4 \cdot 10^{42} \text{(s}^{-1}) = 4.9032918286 \cdot 10^9 \text{(J)} =$$

$$= E_p = \sqrt{\frac{\hbar c^5}{G}} = \sqrt{\frac{6.626070040 \cdot 10^{-34} \text{(J \cdot s)} \cdot \left[0.299792458 \cdot 10^9 \left(\frac{m}{s}\right)^2 \right]^5}{6.67408 \cdot 10^{-11} \left(\frac{m^3}{kg \cdot s^2}\right)}} = 4.90326 \cdot 10^9 \text{(J)}. \quad (10)$$

Mass equivalent $m_G$ of the wave energy $E_G$ (10) of the gravitational field, or its energy mass, which in the framework of Plank’s law energy $E_G = \hbar \nu_G$ and Einstein's law $E_G = m_Gc^2$ on the connection of total energy and mass – its maximum quantum of energy and mass:

$$m_G = \frac{E_G}{c^2} = \frac{\hbar \nu_G}{c^2} = \frac{6.626070040 \cdot 10^{-34} \left(\frac{kg \cdot m^2}{s}\right) \cdot 7.4 \cdot 10^{42} \text{(s}^{-1})}{0.299792458 \cdot 10^9 \left(\frac{m}{s}\right)^2} = 5.455647929 \cdot 10^{-8} \text{(kg)} =$$

$$= m_p = \sqrt{\frac{\hbar c}{G}} = 5.45560 \cdot 10^{-8} \text{(kg)}. \quad (11)$$

This wave parameters gravitational field (7) … (11) are strict physical constants, since they are obtained on the basis of the constants c, h, G.

In [11], [12], for the first time, on strict physical principles, the main energy and force characteristics of the gravitational field were found. Its action is possible through gravitons, which were substantiated in [14] based on the parameters of the minimum quantum of the Universe space [15].

However, in modern works for determining the parameters of the gravitational field [16] – [19], the Maxwell [20] and Lorentz [21] equations are used as a basis. The errors of works [16] – [19] in determining the wave parameters and energy of the gravitational field is that the quantities (5) … (11) in them are not considered strict physical constants, and the field itself, its structure and parameters are taken similar to the electromagnetic field.

Substance and field parameters of the gravitational field obtained in (6) … (11), it allow us to proceed to the determination of its force action [11], [12]. Used of Newton's law (1) is base. Herewith, the total mass $m_I$ of waves of the gravitational
field (12) is replaced by its equivalent on the energy mass $m_G$ (11):

$$m_t = N_G m_G = N_G \frac{h \nu_G}{c^2} (kg).$$

(12)

where $N_G$ – is the number of wavelengths $\lambda_G$ at a distance $r$ to any object having a mass $m_2$:

$$N_G = \frac{r}{\lambda_G}.$$  

(13)

The obtained values (12), (13) allow us to find a new strict physical dependence for the gravitation force $F_G$:

$$F_G = G \frac{m_1 m_2}{r^2} = G \frac{N_G h \nu_G m_2}{r^2 c^2} = G \frac{r h \nu_G m_2}{\lambda_G c^2 r^2} = G \frac{h \nu_G m_2}{\lambda_G c^2} = G \frac{h \nu_G m_2}{\lambda_G c^2} \frac{m_2}{r}.$$ 

(14)

Physical dependence (12), (13), (14) is strict.

Since the constants $G$, $h$, $c$, $\nu_G$, $\lambda_G$ within the framework of their dimensions [11], [12] can be expressed in terms of the Planck's values: length $l_p$ (8), time $t_p$ (7), mass $m_p$ (11), we obtain in strict physical dimension:

$$G \frac{h \nu_G}{\lambda_G c^2} = \left( \frac{l_p^3}{m_p t_p^2} \right) \left( \frac{m_p l_p^2}{t_p} \right) \left( \frac{1}{l_p} \right) \left( \frac{l_p}{t_p} \right)^2 = c^2.$$

(15)

Used (15) and taking into account the value (14); we finally get a strict physical dependence for calculating the force $F_G$ [11], [12]:

$$F_G = c^2 \frac{m_2}{r} = \frac{m_2 c^2}{r} (N).$$

(16)

This dependence (16) implies that the force $F_G$ of the gravitational field action on an object of mass $m_2$ is energetically. It is directly proportional to the total energy $E = m_2 c^2$ of the selected body and inversely proportional to the distance $r$ between it and any selected base of the gravitational field.

In [12] the speed of light $c$ can be obtained through the frequency $\nu_G$ and wavelength $\lambda_G$ gravitational field within the framework of the dependence: $c = \lambda_G v_G$. Based on the dependence $c^2$, this allows you to select the acceleration of free fall $g_G$.
of the Universe, in the form of equality:

\[ c^2 = \left( \lambda_G V_G \right)^2 = \left( \lambda_G V_G^2 \right) \lambda_G = g_G \lambda_G. \]

(17)

From dependence (17) for determining the acceleration of free fall gravity for the gravitational field of the Universe:

\[ g_G = c^2 \lambda_G = \left[ 0.299792458 \cdot 10^9 \left( \frac{m}{s} \right)^2 \right] \cdot 4.051249 \cdot 10^{-35} (m) = 2.2184638 \cdot 10^{51} \left( \frac{m}{s^2} \right). \]

(18)

\[ g_G = c V_G = 0.299792458 \cdot 10^9 \left( \frac{m}{s} \right) \cdot 7.4 \cdot 10^{42} (s^{-1}) = 2.2184638 \cdot 10^{51} \left( \frac{m}{s^2} \right). \]

(19)

Thus, the force of the gravitational field is reduced to the inertial force \( F_G \) [12]:

\[ F_G = \frac{m_2}{r} g_G \lambda_G = \frac{m_2 g_G}{N_G} (N). \]

(20)

However, in [11], [12], new energy and force characteristics of the gravitational field are defined in their maximum state, which is typical for the first moments of the birth of the Universe. This limitation is a common shortcoming of these works. Therefore, their elimination is required, which is the main goal of this work, his scientific novelty is the determination of energy and force characteristics of the gravitational field of comic objects of the planetary level and the deepening of the knowledge obtained on this basis about the foundations of the material world.

The research methods used in the work are based on deduction and induction [22], the general principles of the theory of knowledge and the application of reliable laws of physics.

Research results. Parameters (16) and (20) for determining the strength of the gravitational field were taken as initial parameters for the study. The planetary level objects include the Earth and other individual objects of the Universe. The gravitational acceleration for the Earth \( g_\oplus \) was determined with its average parameters: radius \( r_\oplus = 6.3713 \cdot 10^6 \) m and mass \( M_\oplus = 5.97219 \cdot 10^{24} \) kg [23], according to the dependence (21) [2], which give the numerical value:

\[ g_\oplus = G \frac{M_\oplus}{r_\oplus^2} = 6.67408 \cdot 10^{-11} \left( \frac{m^3}{kg \cdot s^2} \right) \frac{5.97219 \cdot 10^{24} (kg)}{6.3713 \cdot 10^6 (m)^2} = 9.81904 \left( \frac{m}{s^2} \right). \]

(21)
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It was taken into account that force (20) is an energy quantity, therefore, at first, the total energy of the Earth $E_{Gm}$ was determined, which is created by its mass in the framework of Einstein’s law [2] on the relationship between the mass and energy of a physical body:

$$E_{Gm} = M \cdot c^2 = 5.97219 \cdot 10^{24} \text{ (kg)} \cdot \left[0.29979 \cdot 10^9 \text{ (m)}\right]^2 = 0.53675 \cdot 10^{42} \text{ (J)}. \quad (22)$$

It was also taken into account that the radial frequency $\nu_G$ of oscillations of spherical waves of the gravitational field is a constant value [7] – [10], which has a numerical value (5). In this case, the energy $E_{\nu G}$ of one wave of the gravitational field will be the value (23) - its maximum quantum of energy (10):

$$E_{\nu G} = E_p = h \nu_G = 6.62607 \cdot 10^{-34} \left(\frac{\text{kg} \cdot m^2}{s}\right) \cdot 7.4 \cdot 10^{32} \left(\text{s}^{-1}\right) = 4.9033 \cdot 10^9 \text{ (J)}. \quad (23)$$

The number of $N_{EG}$ of such energy gravitational waves (23) within the framework of the total energy of the Earth (22) is the value (24):

$$N_{EG} = \frac{E_{Gm}}{E_{\nu G}} = \frac{0.53675 \cdot 10^{42} \text{ (J)}}{4.9033 \cdot 10^9 \text{ (J)}} = 1.09467 \cdot 10^{32}. \quad (24)$$

The total number $N_\oplus$ of wavelengths of the gravitational field (8) within the mean radius of the Earth $r_\oplus$ is:

$$N_\oplus = \frac{r_\oplus}{\lambda_G} = \frac{6.3713 \cdot 10^6 \text{ (m)}}{4.05125 \cdot 10^{-35} \text{ (m)}} = 0.15727 \cdot 10^{42}. \quad (26)$$

Thus, in the total number of wavelengths (25), the gap between energy gravitational waves (23) is filled by gravitational waves without energy (energy empty waves) in the amount of $N_{AG}$ (26):

$$N_{AG} = \frac{N_\oplus}{N_{EG}} = \frac{0.15727 \cdot 10^{42}}{1.09467 \cdot 10^{32}} = 1.43667 \cdot 10^9. \quad (26)$$

The energy of empty gravitational waves (26) is filled by the environment. For the Earth, it is the energy of the gravitational waves of the Sun, for the Sun, it is the energy of nearby stars and the entire Milky Way galaxy, and so on. However, this energy is many orders of magnitude lower than that of energy gravitational waves (26), because these objects are far away from the Earth.
Schematically, the distribution of these waves and their density are shown in Figs 1.

Rice. 1. *Scheme of the distribution of energy and empty gravitational waves in the Earth's volume*

The gravitational force $F_{\lambda G}$, which is developed by the energy wave of the outermost layer of the Earth's gravitational field (23), is:

$$F_{\lambda G} = \frac{E_{\lambda G}}{r_\oplus} = \frac{4.9033 \cdot 10^9 (J)}{6.3713 \cdot 10^6 (m)} = 0.76959 \cdot 10^3 (N).$$  \hspace{1cm} (27)

Within the framework of the connection between the gravitational force (27), with the free fall acceleration (21), for the outermost layer of the Earth's sphere, we obtain its total value:

$$g_G = \frac{F_{\lambda G} N_{\lambda G}}{M_\oplus} = \frac{0.76959 \cdot 10^3 (N) 1.09467 \cdot 10^{32}}{5.97219 \cdot 10^{24} (kg)} = 1.41062 \cdot 10^{10} \left(\frac{m}{s^2}\right).$$  \hspace{1cm} (28)

For the value of the maximum mass quantum (11), which is equivalent to the maximum energy of the energy gravitational wave (23), we obtain the value of the free fall acceleration:

$$g_G = \frac{F_{\lambda G}}{m_G} = \frac{0.76959 \cdot 10^3 (N)}{5.45565 \cdot 10^{-8} (kg)} = 1.41063 \cdot 10^{10} \left(\frac{m}{s^2}\right).$$  \hspace{1cm} (29)
Results (28) and (29) coincide within the calculation errors, which confirm their correctness.

Since the average value of the force distribution $\Delta F_{vG}$ between empty gravitational waves (26) will be the value (30), and then the acceleration of free fall distributed between them will be the value $\Delta g_G$ (31):

$$\Delta F_{vG} = \frac{F_{vG}}{N_{\lambda G}} = \frac{0.76959 \cdot 10^3(N)}{1.43667 \cdot 10^9} = 0.53568 \cdot 10^{-6}(N).$$

$$\Delta g_G = \frac{\Delta F_{vG}}{m_G} = \frac{0.53568 \cdot 10^{-6}(N)}{5.45565 \cdot 10^8(kg)} = 9.81881 \left(\frac{m}{s^2}\right).$$

Similarly to the value (31), the acceleration $\Delta g_G$ can be obtained by dividing the acceleration (28) by the number of empty waves (26) that are contained in the gap between the energy waves:

$$\Delta g_G = \frac{g_G}{N_{\lambda G}} = \frac{1.41063 \cdot 10^{10} \left(\frac{m}{s^2}\right)}{1.43667 \cdot 10^9} = 9.81875 \left(\frac{m}{s^2}\right).$$

After converting the calculated dependences (22) ... (32), we obtain the acceleration of gravity in its final form:

$$\Delta g_G = \frac{c^2}{r_{bg} N_{\lambda G}} = \left[ \frac{0.299793 \cdot 10^9 \left(\frac{m}{s}\right)}{6.3713 \cdot 10^6(m) \cdot 1.43667 \cdot 10^9} \right] = 9.81879 \left(\frac{m}{s^2}\right).$$

Thus, the real value of the free fall acceleration depends on the size of the object and its energy, expressed as the number of gravitational waves $N_{\lambda G}$ in the packet, which consists of an energy wave and empty waves.

The obtained values of the accelerations $\Delta g_G$ (31) ... (33) coincide with the initial value (21) within the accuracy of the calculations, which is a rigorous proof of the correctness of the method proposed in this work and the wave parameters of the gravitational field found in [7] ... [10]. In this case, the minus deviation of values (31) ... (33) relative to (21) can be compensated by saturation of the energy of empty gravitational waves from external sources. The solution of this problem may be a topic for further research.

The presence of empty energy waves (26) of the gravitational field correlates
with the volumes of voids in atoms and elementary particles of matter that form the volume of the Earth. This is an indirect evidence of the reliability of the work performed; however, further research is required for a rigorous conclusion.

Thus, for all the above transformations, regularities and their numerical values (22) ... (33), there are no contradictions with the known laws of nature, which confirms their correctness. Therefore, they can be considered as new reliable scientific knowledge that expands the level of knowledge of the material world and meets all the signs of a scientific discovery [24].

**General conclusions:**

1. For the first time, the free fall acceleration of cosmic objects was found not through their mass, but through the energy parameters of their gravitational field.

2. The use of the wave and force parameters of the gravitational field, found on the basis of the oscillation frequency \( \nu_G = 7.4 \cdot 10^{42} \text{ s}^{-1} \) (its Nastasenko's frequency constant), allows, on a strict physical basis, to obtain the force and energy parameters of the gravitational field of the planets, as well as the magnitude of their acceleration free fall.

3. The reliability of the found physical and mathematical regularities and their numerical values is confirmed by the same value of the free fall acceleration for the Earth, found in two ways: through its mass and the energy of its gravitational field.

4. The gravitational field of the Earth and similar space objects of the Universe has a layered structure, consisting of spherical gravitational waves. These layers form packets containing one energy gravitational wave with energy \( E = h \nu_G \) and a set of "empty" gravitational waves, the energy of which is associated with the gravitational field of the environment, primarily the Sun.

5. The obtained data and their results can be used for any space objects of the planetary level, therefore, on their basis; the scientific foundations for further research of their gravitation have been created.

6. The found new laws, patterns and their numerical values have the level of scientific discoveries.
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