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Klapchenko Vasily
PhD (Eng.), Associate Professor, Associate Professor of the Department of Physics,
https://orcid.org/0000-0002-4093-5500
Kyiv National University of Construction and Architecture, Kyiv
Kuznetsova Irina
Assistant of the Department of Physics, *https://orcid.org/0000-0003-1800-1733*
Kyiv National University of Construction and Architecture, Kyiv
Krasnianskyi Grygorii
PhD (Eng.), Associate Professor, Associate Professor of the Department of Physics,
https://orcid.org/0000-0002-2421-1270
Kyiv National University of Construction and Architecture, Kyiv

MATERIALITY OF THE GRAVITATIONAL FIELD AND DEVELOPMENT OF PHYSICAL MODELS OF GRAVITATION

Abstract. *Based on the idea of the materiality of the gravitational field, two physical models of gravity are proposed: Model 1 – the equivalent scheme of gravistatics and Model 2 – the vacuum profile of withdrawals from the physical vacuum in the region of a black hole. Model 1 clearly illustrates the fundamental difference between electrostatic interaction and gravity. In particular, it confirmed the validity of the Mach principle, the presence of a double action of the gravitational field and the huge (but not infinite!) gravity propagation speed υg ~ 1069 m/s. Model 2 made it possible to distinguish between the phenomena of the expansion of the universe and the recession of galaxies, to understand their physical essence and to obtain Hubble's law. An important achievement of the model should be considered that the interpretation of these phenomena is based on the features of gravity and does not require the involvement of ideas about additional substances – dark matter and dark energy. The most important common achievement of the models is their ability to explain the gravitational spontaneous generation of the universe – the emergence of a metastable Metauniverse, within which a large number of universes simultaneously appear. This explanation involves the whole complex of features of gravity, emphasized by the models themselves. In particular, the spontaneous generation of the universe does not run into the problem of singularities and does not require far-fetched effects such as an inflationary stage of expansion or special vacuum states.*

Keywords: gravity; physical vacuum; expansion of the universe; the recession of galaxies; Hubble's law; the gravitational spontaneous generation of the universe; metastable state of the Metaverse

Preface

The attraction of ideas about the materiality of the gravitational field, begun by L. Brillouin [1] and continued by us [2], opens the way to the application of physical (object) modeling in gravity. In contrast to the mathematical modeling initiated by Heaviside [3] and focused on the creation of Maxwell-like theories of gravity, physical modeling improves the understanding of gravity and its differences compared to other types of interactions, and also generates several new ideas.

In particular, equivalent circuit modeling emphasizes the difference between gravity and electrostatics, points to the dual action of the gravitational field, confirms the validity of Mach's principle, and supports long-standing ideas about the almost infinite speed of gravity propagation. However, the most powerful model is the vacuum profiling of black holes, which changes not only our understanding of the Universe as a whole but also our view of its origin.

The application of the black hole vacuum profile model removes the issues of dark energy in our Universe, showing how the antigravity effect occurs within Universe-the Black Hole. In this consideration, Hubble's law appears naturally, and the concepts of the expansion of the Universe and the recession of galaxies are also separated. In the end, within the framework of this model, the idea arises of the fluctuating origin of our Universe simultaneously with many other universes.

Purpose of the work

The purpose of the work is to confirm the fact that only with the advent of physical models of gravity is it possible to advance our understanding of this phenomenon and its role in the Universe as a whole. We intend to achieve this goal without the unnecessary application of mathematical transformations. At the same time, this will fix another fact – no "mathematical conjectures", that is, mathematical modeling in gravity, can close the gaping gap between the mathematical form of the law of gravitational interaction and the essence of the phenomenon of gravity.

Basic material

Model 1: Gravistatics Equivalent Scheme

The validity of the Mach principle for the gravitational field, demonstrated by us in [2], allows us to represent the formation of any mass in the Universe in the form of an equivalent scheme in Fig. 1*a*, which is similar to the scheme for generating a charge on a body using a galvanic connection of this body with the corresponding pole of an electric battery (Fig. 1*b*). Unlike electrostatics, which allows an idealized method of obtaining a charge on a body (Fig. 1*c*) by sequentially transferring small portions of charge to it from infinity, gravitational interaction does not imply such a method of obtaining an “isolated” mass.

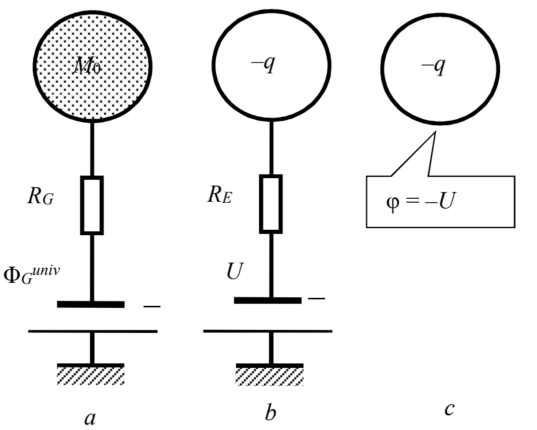

Figure 1 – Equivalent schemes for the formation of mass or charge: a) formation of the charge-mass of the body by the universal potential Φ_G^{univ}; b) accumulation of charge on the body using an electric battery U; c) the charge of the same magnitude, brought from ∞, forms the same body surface potential U

The analog of the "gravitational" battery in the circuit (Fig. 1*a*) is the averaged gravitational potential $\Phi_G^{univ} = -c^2$. In the future, also by analogy, it is possible to introduce the *gravitational resistance* R_G into the scheme and provide for the existence of a value C_G equivalent to the electric capacitance – the *gravitational capacitance* (or the gravitational capacitance of a capacitor when two or more bodies approach each other).

The first thing that can be seen in the analysis of the equivalent circuits is that there is a fundamental difference between gravistatics and electrostatics. Because Coulomb's law with charges constant in magnitude can be obtained only by the interaction of isolated charges (Fig. 1*c*), while the law of universal gravitation with masses constant in magnitude appears only when two masses interact with a "galvanic" method of formation (Fig. 1*a*). Direct verification of the interaction of masses according to the scheme of Fig. 1*a* completely reproduces the results obtained in [2].

Secondly, from the analysis of equivalent circuits, the effect of the mass increase in the gravitational interaction becomes clear. This is a kind of capacitive effect, understandable to us by considering the electrostatic interaction of charges connected to an electric battery (Fig. 1*b*). In electrostatics, this effect is extremely pronounced, since the mutual electrical capacitance of a system of interacting bodies (the capacitance of a capacitor) can be many times greater than the total capacitance of individual charged bodies. Such a "capacitor" effect in gravistatics is much weaker, however, with an increase in the number of interacting masses, its manifestation becomes significant, leading to a macroscale gravitational collapse [2].

Thirdly, back in [2], we used the peculiarity of the formation of charges according to the scheme in Fig. 1*b* and charge-mass according to the scheme in Fig. 1*a*. There we focused only on the effect of the *double action* of the gravitational field, which was based on the ratio between the energy of the formed electric charge $qU/2$ (which is half the expenses of the electric battery for its creation) and the energy of the formed charge-mass m_0c^2 (which coincides with the expenses of the equivalent gravitational battery).

However, the noted energy relations emphasize two more important features of the gravitational interaction. One of them points to the existence of *gravitational superconductivity*. The analysis of the equivalent circuit of the galvanic method of charge formation (Fig. 1*b*) leads to this conclusion. When charging a capacitor by connecting it to an electric battery, we always lose half of the battery's energy on heat generation in the lead wires. In this case, the share of losses (1/2) does not depend on the value of the electrical resistance R_E, but only on its presence, that is, it is fundamental only that $R_E > 0$. Therefore, the absence of such losses during the formation of charge-mass according to the scheme of Fig. 1*a* should be associated with the absence of an equivalent gravitational resistance R_G, that is, $R_G \equiv 0$.

Another feature characterizes not so static as rather dynamic properties of gravity. In particular, in the scheme of charge formation with the help of an electric battery (Fig. 1*b*), an estimate of its growth rate or its decrease through the relaxation time $\tau_E = R_EC_E$ is provided. It is important that this time is finite and we perceive it as limiting the speed of propagation of electromagnetic processes by the speed of light. In the charge-mass formation scheme (Fig. 1*a*), the relaxation time is $\tau_g = R_GC_G = 0$. One can say more cautiously: this time is not defined and the only true thing is that it is very small, that is, it approaches zero $\tau_g \to 0$. Therefore, we have every right to choose for the time of gravitational relaxation for our Universe the smallest of the time intervals known to us – the Planck time $T_P = 5.4\cdot10^{-44}$ s. Then the characteristic time for the complete development of gravity will be in the order of magnitude $\tau_g \sim 10T_P \sim 5.4\cdot10^{-43}$ s.

And this allows us to estimate the speed of propagation of gravity by the value $\upsilon_g = R_g/\tau_g \sim 10^{69}$ m/s (R_g is the radius of the Universe), which is many orders of magnitude higher than the speed of light. However, it is very important, and in the future it will become clear that the speed of propagation of gravity is although large but *finite*. Because the low speed of the gravity propagation would cast doubt on the validity of Mach's principle. And an infinitely high speed of propagation would make the very process of the birth of the Universe problematic. Now we can only assume that under the concept of "long-range action" in relation to gravity, Newton had in mind just a large but finite speed of its propagation. The same balanced opinion was shared by Laplace, who gave a quantitative estimate of the transfer rate of gravitational interaction as a quantity 10^9 times greater than the speed of light. This estimate was based on calculations of gravity within the solar system.

Model 2: Black Hole Vacuum Profile

Model formation. Model 2, called in [4] the black hole vacuum profile, arose in the analysis of the formula for determining the radius of the black hole horizon r_g, which, according to [2], has the form:

$$r_g = \gamma\frac{M_0}{c^2} = \gamma\frac{2M_K}{c^2}, \qquad (1)$$

where M_0 is the total mass of the black hole, $M_K = M_0/2$ is the mass of all bodies that fall inside the sphere of radius r_g. We called it the *kern mass* of the black hole M_K (from the German *kern* – core, essence). The second half of the black hole mass, also equal to M_K, is outside the radius r_g and is its *field mass*. Note that, written in terms of the kern mass, formula (1) coincides with Schwarzschild's formula for the gravitational radius of a black hole [5].

This made it possible to introduce the concept of the *average linear density of matter* $\overline{\rho}_L$ falling inside a sphere with the black hole horizon radius r_g. Later [4], this value was called the *maximum density of extractions from the physical vacuum* ρ_{vac} in the region of the black hole kern:

$$\overline{\rho}_L = \frac{M_K}{2r_g} = \frac{c^2}{4\gamma} = \rho_{vac}. \qquad (2)$$

The introduced linear density is a combination of world constants, the numerical value of which is $\overline{\rho}_L = \rho_{vac} = 3.3\cdot10^{26}$ kg/m. The first conclusion drawn from this is that any spherical region of radius r_g, located inside an existing black hole and filled with material bodies, itself becomes a black hole if only it (inside a sphere of radius r_g) contains the corresponding kern mass:

$$M_K = \rho_{vac}\cdot 2r_g. \qquad (3)$$

This ratio should be considered a necessary mass condition for the appearance of a black hole within the existing one. At the same time, this ratio can be considered as half of the energy condition that provides the energy for the appearance of a black hole, because the other half of the energy condition is "provided" by the existing black hole. We will talk about this further. The full vacuum profile arises after trying to determine the field mass around the black hole kern in terms of the sum of withdrawals from the physical vacuum outside the radius r_g of the black hole:

$$M_K = -2\int_{r_g}^{\infty}\overline{\rho}_L\left(r_g/r\right)^n dr = 2\overline{\rho}_L r_g(n-1), \qquad (4)$$

whence we obtain $n = 2$ and the final profile pattern takes the form of Fig. 2. Note that the masses themselves in the composition of the black hole kern as three-dimensional objects cannot be reflected on this linear profile.

In Fig. 2, the following draws attention. The distribution of the relative linear density of extractions from the physical vacuum $\rho_L(r)/\overline{\rho}_L$ repeats the distribution of the relative gravitational potential $\varphi_g(r)$ for a similar black hole [4]. To prove the correlation of these quantities, a whole section on the *saturation of the gravitational potential* when approaching the state of a black hole was devoted to this in [4].

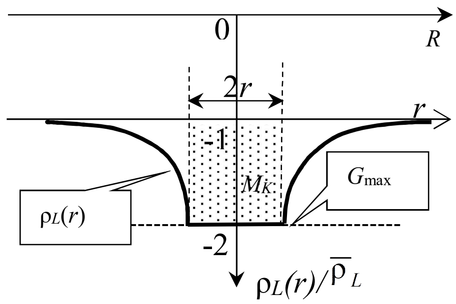

Figure 2 – The distribution of the linear density of withdrawals $\rho_L(r)$ from the physical vacuum for a formed black hole in an existing black hole. The number "0" indicates the zero level of withdrawals of the existing black hole

The simplest explanation is provided by this analogy. A black hole is analogous to a conductor in electrostatics: the surface of the conductor and all points of its volume are an equipotential surface. In particular, in the kern area, the regularity is exactly fulfilled: the decrease in the density of withdrawals from the physical vacuum by the value ρ_{vac} occurs synchronously with the decrease in the gravitational potential in the kern area by the value $\Phi_G^{univ} = -c^2$. That is, all points of the horizon of a black hole (a sphere of radius r_g) and all points of its kern, with a uniform distribution of masses over the volume, have a decrease in the average relative gravitational potential by $\overline{\varphi}_g = -1 = \mathrm{const}$ compared to the relative potential of the universe, if it is taken as 0.

A similar decrease in the relative gravitational potential by the value $\bar{\varphi}_g = -1$ occurred, but much earlier, in the existing black hole. All this makes it possible to formulate the complete energy condition for the appearance of a black hole. To do this, we use the mathematical form of the Mach principle, which we gave to it in [2]. It represents a kind of *zero energy conservation law* at the birth of a black hole within an existing black hole. Indeed, if the potential energy of the gravitational interaction of the black hole kern masses, taken with a minus sign, is equal to the rest energy of the black hole, then this can be written as follows: $-W_G = M_0c^2$. Dividing the potential energy of the gravitational interaction into two parts – the internal interaction W_{Gin} (the interaction of the kern bodies with each other) and the external interaction W_{Gex} (the interaction of the kern masses with other bodies of the existing black hole), we obtain the condition:

$$W_{Gin} + W_{Gex} + M_0c^2 = 0. \quad (5)$$

It is easy to check that when a black hole appears within the existing one, that is, when condition (3) is met, relation (5) turns into an identity.

Mass, gravity and the hierarchy of times. It should be noted that the formation of the black hole vacuum profile model (Fig. 2) was preceded by a lot of work. It all started with the ideas of Zeldovich [6], which gave rise to a firm belief that any bodies or individual particles in our Universe originate from the physical vacuum, that is, its components act as the “material” for the formation of massive bodies. This is how we approached the necessity of modeling the physical vacuum, in particular, in [7]. The hints for such modeling were the following: the existence of an average linear density (2) and the phrase of D. Uspensky [8] “The world is woven from thin lines wound on cylinders.”

The result of the modeling was the idea that the physical vacuum is a kind of three-dimensional trampoline, organized by continuous-discrete structural elements stretched across the entire universe – a kind of *strings* with a discrete structure. Such strings form a dense grid (fan) of linear elements penetrating every point of the physical vacuum. Convolutions of similar strings, allowed by their discreteness, when localized in the appropriate place, represent a kern (body base), around which there is a corresponding decrease in the density of the physical vacuum, “felt” due to a decrease in the gravitational potential.

For example, the formation of a black hole as a sphere of radius r_g means that several linear elements *are removed* from the physical vacuum within this sphere, the linear density of which, assembled in one line, is already known to us linear density (2). That is all these removed linear elements formed convolutions, forming the mass of the black hole kern. Outside the sphere r_g, the density of the removed line elements falls in inverse proportion to the square of the radius $\Delta\rho_{vac} = \rho_{vacL}(r_g / r)^2$. All this is presented in Fig. 2 as a profile of extraction from the physical vacuum during the formation of a black hole with a uniform initial distribution of masses (absent in the figure) over the volume of its kern.

How to combine such model representations with the fact that the insensitivity (weightlessness, masslessness) of the physical vacuum is well-known? Following our model, we should clarify the basic concepts for ourselves. *Body mass* (manifested mass) is part of an *ordered* physical vacuum (convolution of its linear structures), which gravitationally (or by other forces) interacts with surrounding bodies. *Energy* is the measure of physical vacuum ordering, which is why $W = mc^2$. Gravity is an *essential attribute of mass*. Gravity manifests itself with some delay $\tau_g = R/c_g$, depending on the size of the system R, in which this mass appears. And it does not matter whether the mass arose as a result of the introduced external energy, whether we are talking about virtual masses that appear fluctuationally.

So we have come close to the central question of the origin of the mass. Let's say right away that black holes are directly related to this, so we consider the physical modeling of gravity problems using the vacuum profile of a black hole. Considering that it is gravity that will act as a source of energy during the spontaneous generation of mass, and it appears with a delay in time, an important role, in addition to relations (3) and (5), will be played by the *temporal hierarchy*. We will pay attention to this in the paragraph "fluctuational origin of the universe". And now let's look at examples of why there is no spontaneous generation in the existing black hole, which is our Universe. In particular, virtual particles and antiparticles are constant "candidates" for such spontaneous generation. However, this does not happen, because conditions (3) and (5) are simultaneously violated for them, which are exactly satisfied only for black holes.

Then why do we not observe the intense fluctuating spontaneous generation of black holes in our Universe? Let's say the smallest black holes (see line 1 in Table 1), which were so feared before the launch of the Large Hadron Collider. Because the hierarchy of times interferes. Such a fluctuation, according to quantum mechanics, exists in the time interval $\Delta\tau \sim \hbar/2m_Pc^2 \sim 2\cdot10^{-44}$ s, whereas much more time ($\tau_g \sim 5.4\cdot10^{-43}$ s) is needed for the development of gravity and the achievement of an irreversible state of a black hole. It is clear that the fluctuation generation will also be unacceptable for black holes of larger mass, for example, with the size of an atomic nucleus (line 2 of Table 1). So microscopic black holes should not be feared, and macroscopic black holes should be treated with respect – we just live in one of them.

General patterns. Let's try, using the black hole vacuum profile model (Fig. 2), to highlight the general characteristics of black holes in our Universe. Let's add some additional parameters to Fig. 2. In particular, using the value of the average linear density of the black hole kern matter (2), we determine the value of the kern mass M_K (3), the average volumetric density of the kern matter $\bar{\rho}_V = M_K/V$ and the maximum acceleration $G_{\max} = 2\gamma M_K/r_g$ in the vicinity of the black hole for some characteristic values of its gravitational radius r_g. These parameters are summarized in Table 1.

*Table 1 – **Associated parameters of black holes at different values of their radius r_g***

#	r_g, m	M_K, kg	$\bar{\rho}_V$, kg/m³	$G_{\max}$, m/c²
1	$1.6{\cdot}10^{-35}$	$1.1{\cdot}10^{-8}$	$0.6{\cdot}10^{96}$	$5.5{\cdot}10^{51}$
2	$1.0{\cdot}10^{-15}$	$6.6{\cdot}10^{11}$	$1.6{\cdot}10^{56}$	$8.8{\cdot}10^{31}$
3	$2.0\ 10^{4}$	$1.3{\cdot}10^{31}$	$4.0{\cdot}10^{17}$	$4.4{\cdot}10^{12}$
4	$1.0{\cdot}10^{13}$	$6.6{\cdot}10^{39}$	1.6	$8.8{\cdot}10^{3}$
5	$1.6{\cdot}10^{-35}$	$1.1{\cdot}10^{-8}$	$0.6{\cdot}10^{96}$	$5.5{\cdot}10^{51}$

Firstly, we have already noted the fact that the distribution of the relative linear density of extractions from the physical vacuum (Fig. 2) repeats the distribution of the relative gravitational potential $\varphi_g(r)$. In addition, at the initial stage of the appearance of a black hole, its potential "bottom" is always flat. More precisely, with a uniform distribution of masses in the volume of the kern, the "bottom" is similar to "ripples on the water", which cannot be displayed on our scale – it's just a horizontal line. Accordingly, the potential gradient, and hence the strength of the gravitational field in the region of the black hole kern, is actually equal to zero. And those grandiose field strengths (see the last column of Table 1) around the black hole are absent in the kern region. No additional gravitational pressures take place in the kern area and do not cause destructive compression of this area.

Secondly, in addition to the potential "bottom" of a black hole, it is necessarily surrounded by "gravitational wings", in which half of the mass of the black hole is concentrated – its field mass. The proposed model makes it possible to determine that the *stability* of a black hole as a specific material formation is precisely ensured by this invisible gravitational "shield" surrounding the kern of a black hole. This shield has *one-sided gravitational permeability* – any bodies and radiation easily penetrate the kern area from the outside, while not only particles of matter but also radiation is not able to get out of the kern area. It can even be proved that the radiation from the kern region does not fall into the region of "gravitational wings" at all, being reflected at the points of the sphere of radius r_g as from an ideal *gravitational dielectric mirror*.

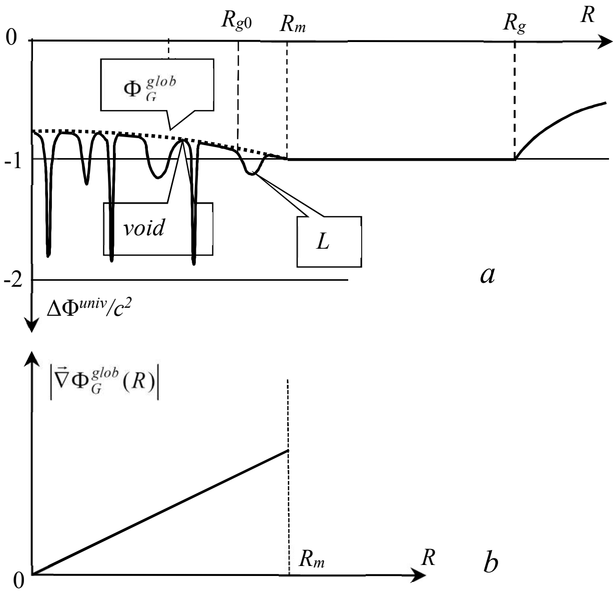

Figure 3 – Antigravity and recession of galaxies: a) distribution of the local gravitational potential in our Universe (solid line). The global distribution of the potential in the material part of the Universe is shown by a dotted line Φ_G^{glob}; b) dependence of the modulus of the global potential gradient (acceleration of the recession) on the distance to the center of the Universe R

Not only the incredible stability of such a material formation as a black hole is very important but also the *irreversibility of the process* of its formation. We will note this for the future. And first of all, the possibility of representing such formations as an *equivalent gravitational battery* with virtually unlimited gravitational capacity and a constant electromotive force $\Phi_G^{univ} = -c^2$ is striking. This circumstance was used in the formation of Model 1. In particular, if an additional mass enters the black hole as a result of accretion from the outside, then this does not change the potential Φ_G^{univ} but leads to the expansion of the black hole, that is, an increase in the radius r_g. However, something else is more interesting. The expansion of a black hole is also possible due to internal processes within the kern of a black hole. For example, when clusters of bodies (or even black holes [2]) appear in the region of the black hole kern, the mass gain due to gravitational interaction automatically leads to its expansion without violating the stability of this formation. In this case, the potential "bottom" of the black hole will cease to be absolutely flat and acquire a more complex profile.

Thirdly, while working on the models discussed here, we somewhat revised our previous ideas about the conditions for the emergence of black holes in the universe and their possible spectrum. Briefly, the change in these views is illustrated in Table 1. It presents a wide range of radii r_g allowed in our Universe – from the Planck size (line 1 of Table 1) to the size of our Universe (line 5 of Table 1). Because of the foregoing, we are confident that the necessary conditions for the appearance of black holes in the Universe can be met only for those characteristic sizes that are presented in lines 3, 4 and 5 of Table 1.

In particular, line 3 describes the parameters of the most theoretically studied class of black holes – *stellar masses* – as one of the neutron star collapse scenarios [9, 10]. A necessary condition for their occurrence is the allowable average density of the kern (density of nuclear matter). Achieving such a kern volumetric density can be theoretically envisaged and implemented practically.

Line 4 singles out the class of *supermassive black holes* capable of appearing both at the stages of gas clusters ($\overline{\rho}_V = 1.6$ kg/m^3) and the stage of formation of star clusters. As we have shown in [2], the transformation of stellar clusters into supermassive black holes is "assisted" by macroscale gravitational collapse, the appearance of which is a consequence of the materiality of the gravitational field. Such black holes are a kind of micro-universes (billions of stars) in which even the origin of life can be expected. In our opinion, this class of black holes in the Universe is preferable.

Line 5 of Table 1 describes the parameters of a separate class of black holes – black holes the size of the universe. The parameters given there are very close to those we know about our Universe. We emphasize that for black holes of this class (in other words, universes), the necessary mass condition (3) for their transformation into a black hole can be satisfied at any time due to the presence of virtual particles in an empty physical vacuum. However, the realization of this possibility is limited by other conditions and therefore occurs as an extraordinary event. We will dwell on the fluctuating origin of the Universe separately.

Antigravity, Hubble's law and the recession of galaxies. We will assume that in the three previous paragraphs we have sufficiently familiarized ourselves with Model 2 and are accustomed to working with it. Using Model 2, let us consider the stage of the mature universe – the stage of developed stars and star clusters, black holes and unclear clusters of invisible mass (dark matter) and energy (dark energy) [11].

According to Model 2, this stage of development can be schematically represented as follows (Fig. 3*a*). The bold line *L* (rather complex in shape) in the figure marks the density profile of extractions from the physical vacuum, which simultaneously coincides with the distribution of the relative gravitational potential in the vicinity of the level $\Phi_G^{univ}/c^2 = -1$ marked by a thin horizontal line. The distances *R* from the center of the universe to the characteristic points are shown along the horizontal axis in Fig. 3*a*. In particular, R_{g0} is the gravitational radius of the universe at the time of birth, R_m is the radius of the massive part of the universe today, and R_g is the current gravitational radius of the universe. Between the points R_m and R_g, there is a massless part of our Universe – there are no particles of matter and even radiation.

The "bottom" profile is no longer flat everywhere because potential dips (dips in the density of withdrawals) have appeared in the places of star clusters and black holes, as well as corresponding rises between them (they are called *voids*). Voids are massless sections of the universe. Such a profile arises because the average value of the density of extractions from the physical vacuum (2) over the entire area of the black hole kern must remain unchanged (always and absolutely exactly!). Compared to the real "relief", the profile drops in the figure are significantly overestimated to achieve a more visual picture. The bypass curve is shown in the figure by a dashed line and is designated as Φ_G^{glob} passes along the upper edges of the potential profile and is called by us the *global distribution of the potential* in the universe.

Now let's show how Model 2 separates two phenomena – the expansion of the universe and the recession of galaxies. In particular, the *expansion of the universe* is a consequence of the growth of the energy-mass of the universe due to the internal gravitational interactions of the bodies in it.

First of all, we are talking about the growth of kinetic energy due to the work of gravity to bring together massive bodies. In addition, there is an additional increase in the rest mass of bodies in gravitational interactions. This follows from [2] and is an obvious consequence of Model 1. Moreover, in large clusters, both growth effects become nonlinear, which gives a reasonable hope that the total mass of our Universe can be explained without involving the concepts of dark matter. The very phenomenon of the expansion of the universe is reduced to an instantaneous increase in the gravitational radius R_g of the universe following formula (3), as soon as its mass increases. In our opinion, this is not accompanied by the propagation of gravitational waves but looks like a *gravitational shaking* during the time $\tau_g \sim R_g/\upsilon_g = 5.4\cdot 10^{-43}$ s. Such shaking can be registered on the same sensitive installations that provide for the registration of gravitational waves.

The phenomenon of the *recession of galaxies* of another nature. It is based on the configuration effect of the entire set of masses in the region of the black hole kern. Briefly, it can be called the *anti-gravity* effect. A variant of its implementation is shown in Fig. 3*a* in the form of a specific curve $\Phi_G^{glob}(R)$ of the global potential distribution in the universe. The nature of the global distribution is determined by the fact that in the central regions of the Universe per unit volume the concentration of clusters of stars and black holes is higher than in the points of the periphery that are far from the center.

Then the gradient of the global potential distribution $\vec{\nabla}_R \Phi_G^{glob}(R)$ will be minimal (more precisely, equal to zero) at the center of the universe, and maximal at the edge of the mass part of the universe R_m. For a particular section of the universe, intermediate values of this gradient between 0 and R_m can have any dependence on R, but averaging these dependencies for many randomly chosen sections will lead us to a linear law (Fig. 3*b*). In terms of physical content, this gradient (taken with the "minus" sign) is the free fall acceleration g^{glob}, directed along the radius R from the center to the periphery, which gave the right to call the effect antigravity. If the linear dependence of this acceleration (Fig. 3*b*) is represented as $g^{glob} = \beta R$ and we take into account that the speed is the product of the acceleration and the time of its action T, then we get

$$\upsilon_g = g^{glob} \cdot T = \beta TR = HR. \quad (6)$$

Relation (6) has been established experimentally and is known to us as Hubble's law. Based on our model consideration, we come to the following conclusions. Firstly, the Hubble constant $H = \beta T$ cannot be inversely proportional to the lifetime of the universe. Secondly, the time T in (6) also cannot exactly coincide with the lifetime of the universe, because this is only the time duration of the recession phase of galaxies. Thirdly, Hubble's law is not a law of nature, it manifests itself only in certain configurations. In this case, it is valid only for large accumulations of masses, for example, galaxies. At the same time, individual bodies move under the action of gradients of *local potential distributions*, which are orders of magnitude greater than the magnitude of the global distribution gradient. In particular, in the region of voids, local accelerations of bodies are also oriented from the center of the void to its periphery. That is, there is also a kind of anti-gravity effect. If there were observers in the centers of the voids, they would fix several local Hubble's laws (something similar to formula (6)) and would call it the laws of the recession of stars. Fourthly, the mathematical representation of Hubble's law in the form $\upsilon_g = dR/dt$ is fundamentally wrong, since the coordinate R has no connection with the acquired speed. And fifthly, the emergence of a physical justification for Hubble's law deprives us of the need to use the concept of dark energy to explain the effect of the recession of galaxies.

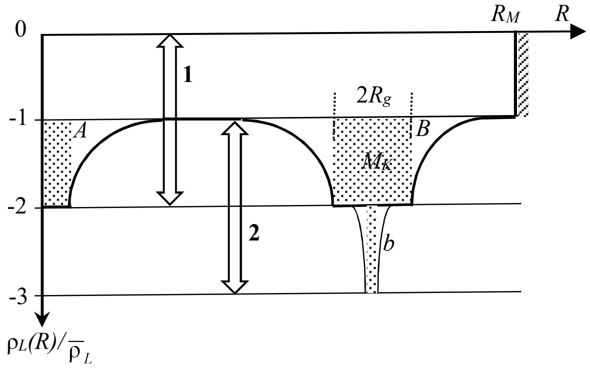

Figure 4 – Metaverse and hierarchy of black holes in nature. A, B – separate universes, b – a black hole in one of the universes

Fluctuation origin of the Universe. When discussing the proposed models, in one way or another, the question arose about the possibility of the gravitational spontaneous generation of the universe. Two circumstances directly point to the realism of such a scenario. The first of them is based just on the fluctuation ability of the physical vacuum to produce virtual pairs of particles and antiparticles in it. Only 500 virtual electron-positron pairs per cubic meter are enough for the necessary condition (3) to be fulfilled in a volume with the characteristic size of our Universe. The second circumstance also emphasized in the previous discussion, is that the process of spontaneous generation will become irreversible if it ends with the formation of a black hole, that is when the full energy condition (5) is satisfied. However, a unit universe will not arise in the primary physical vacuum, because there is no gravitational interaction with other (external) bodies, and therefore condition (5) for unit universes cannot be fulfilled.

As analysis has shown, there is only one way of such gravitational spontaneous generation: the fluctuation formation of a *metastable* metauniverse, in which a large number of identical universes *simultaneously* arise. Schematically, this moment of creation is shown in Fig. 4. It represents a kind of hierarchy of the largest black holes in Nature. The approximate hierarchy of linear scales of these black holes, which, of course, is strongly distorted in the figure, can be imagined by the following values: $R_M \sim 10^{40}$ m is the gravitational radius of the Metaverse, $R_g \sim 10^{26}$ m is the gravitational radius of a separate universe (for example, *B*), $r_g \sim 10^{13}$ m is the gravitational radius of the future black hole (*b*) in the mature universe (line 4 of Table 1). Perhaps some other super-large hypothetical formation $R_S \sim 10^{60}$ m in the primary vacuum should also be envisaged – for a clear understanding of the hierarchy of times. Already at this size, the time of gravity development outside Metamir becomes too "large" – $\tau_{gS} \sim R_{gS}/\upsilon_g \sim 10^{-9}$ s, which exceeds any other time intervals.

The mass-energy hierarchy of black holes in Fig. 4 is underlined by double arrows 1 and 2. It is in this simple way that our Model 2 fixes the exact fulfillment of the full energy condition (5) when a black hole of the lowest rank appears. Therefore, the only inferior black hole, the hole of the highest rank, is the Metaverse. In Fig. 4, this can be seen from the fact that the Metaverse ends with a sharp break in the profile of withdrawals from the physical vacuum, without the usual "gravitational wings". This state is metastable, it arises only due to the fulfillment of a certain hierarchy of times, which looks amazing – in this hierarchy of times, the Metaverse is "stuck" forever.

Taking into account the randomness of the fluctuation origin of a large number of universes, it is necessary that in the hierarchy of times the time of existence of seed elements – virtual particles and antiparticles – have the greatest extent. It is the highest for electron-positron and hadron-anti-hadron pairs and amounts to $\Delta\tau \sim \hbar/2mc^2 \sim 10^{-(21...24)}$ s. In the shortest possible time $\tau_g \sim R_g/\upsilon_g = 5.4\cdot10^{-43}$ s within each universe, the gravitational interaction W_{Gin} develops and condition (3) is fulfilled. A much longer time – $\tau_{gM} \sim R_{gM}/\upsilon_g \sim 10^{-29}$ s – is necessary for the emergence of "gravitational wings" in each universe and the appearance of the potential energy of gravitational interaction between universes W_{Gex}.

That is, the time $\tau_{gM} \sim 10^{-29}$ s is sufficient for condition (5) to be exactly fulfilled for each of the universes and for all of them to turn into black holes. From this moment on, the process of generation becomes irreversible, even though only condition (3) is fulfilled for the Metaverse. And condition (5) will never be fulfilled for it (but it will never be violated either!), because this requires time for the development of its "gravitational wings" $\tau_{gS} \sim 10^{-9}$ s, which becomes an eternity. Such a metastable Metaverse will not have gravitational interaction with the surrounding world.

Note that the above scenario of spontaneous generation serves only as a demonstration of the capabilities of the proposed models. A full and detailed discussion of it awaits us in the future. Therefore, we consider it necessary to add to it an important, as it seems to us, detail. In the beginning, each newborn universe goes through a *photonic* stage. This follows from the condition of fluctuation spontaneous generation based on a set of virtual pairs of particles and antiparticles. At the moment of materialization, all this mass of particles and antiparticles (~ 10^{50} tons!) instantly annihilates, forming a hard spectrum of annihilation radiation. And it looks like an explosion! And after many complex transformations, radiation becomes familiar to us matter (or antimatter) for different universes. On this occasion, the book "Photon Theory of Matter" was written [12].

Conclusions

1. Both models of gravity are a direct consequence of the validity of the assumption about the materiality of the gravitational field, as well as any other force field. However, in the case of gravity, this leads to the idea of a double action of the field – the appearance of the effects of a static and dynamic increase in energy-mass. In large accumulations of masses, the increase in energy-mass becomes non-linear, which "facilitates" the emergence of macroscale gravitational collapse and the appearance of supermassive black holes. From here, a model idea of gravity appears – as a specific way of organizing matter due to the withdrawal of its linear structures from the physical vacuum, accompanied by additional extractions in the form of "gravitational wings" (i.e. the appearance of a field mass), which we perceive as a gravitational field.

2. Briefly about the possibilities of models. Model 1 emphasizes not only the double action of the gravitational field but also the validity of the Mach principle, gravitational superconductivity and extremely high (but not endless!) speed of propagation of the gravitational field $\upsilon_g = R_g/\tau_g \sim 10^{69}$ m/s. Model 2 makes it possible to distinguish between the phenomena of the expansion of the universe and the recession of galaxies, to understand their physical essence and to obtain Hubble's law. An important achievement of the model should be considered that the interpretation of these phenomena is based on the features of gravity and does not require the involvement of ideas about additional substances – dark matter and dark energy.

The most important common achievement of the models is their ability to explain the gravitational spontaneous generation of the universe – the emergence of a metastable metauniverse, within which a large number of universes simultaneously appear. This explanation involves the whole complex of features of gravity, emphasized by the models themselves. In particular, the spontaneous generation of the universe does not run into the problem of singularities and does not require far-fetched effects such as an inflationary stage of expansion or special vacuum states.

3. In conclusion, the analysis of the models indicates that some effects are hidden in the features of gravity, which could be of great practical importance. Their discussion may be the subject of another publication.

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Клапченко Василь Іванович
Кандидат технічних наук, доцент, доцент кафедри фізики, *orcid.org/0000-0002-4093-5500*
Київський національний університет будівництва і архітектури, Київ
Кузнецова Ірина Олександрівна
Асистент кафедри фізики, *orcid.org/0000-0003-1800-1733*
Київський національний університет будівництва і архітектури, Київ
Краснянський Григорій Юхимович
Кандидат фізико-математичних наук, доцент, доцент кафедри фізики, *orcid.org/0000-0002-2421-1270*
Київський національний університет будівництва і архітектури, Київ

МАТЕРІАЛЬНІСТЬ ГРАВІТАЦІЙНОГО ПОЛЯ І РОЗВИТОК ФІЗИЧНИХ МОДЕЛЕЙ ГРАВІТАЦІЇ

Анотація. *На основі ідеї про матеріальність гравітаційного поля запропоновано дві фізичні моделі гравітації: модель 1 – еквівалентна схема гравістатики; модель 2 – вакуум-профіль вилучень з фізичного вакууму в області чорної діри. Модель 1 наочно ілюструє принципову відмінність між електростатичною взаємодією та гравітацією. Зокрема вона підтвердила справедливість принципу Маха, наявність подвійної дії гравітаційного поля та величезну (але не нескінченну!) швидкість розповсюдження гравітації* $\upsilon_g \sim 10^{69}$ *м/с. Модель 2 дозволила розрізнити явища розширення Всесвіту і роздалення галактик, зрозуміти їх фізичну сутність і отримати закон Хаббла. Важливим здобутком моделі слід вважати те, що тлумачення цих явищ ґрунтуються на особливостях гравітації і не вимагають залучення уявлень про додаткові субстанції – темну матерію та темну енергію. Найважливішим спільним досягненням моделей є їх здатність пояснити гравітаційне самозародження всесвіту – виникнення метастабільного Метавсесвіту, в межах якого одночасно з'являється велика кількість всесвітів. До цього пояснення залучено весь комплекс особливостей гравітації, підкреслених самими моделями. Зокрема, самозародження всесвіту не наштовхується на проблему сингулярностей, не вимагає надуманих ефектів типу інфляційної стадії розширення або особливих станів вакууму.*

Ключові слова: гравітація; фізичний вакуум; розширення всесвіту; розбігання галактик; закон Хаббла; гравітаційне самозародження всесвіту; метастабільний стан Метавсесвіту

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