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ROTATION CURVES, GRAVITY, MATTER, ENERGY, EQUATIONS OF NEWTON AND MOTION IN COSMOLOGY

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We consider bodies moving at very high speeds. In this case, the mass of these bodies depends on their speed. Using this information, we model the rotation curves of galaxies and their clusters. Speeds close to the speed of light are examined using examples of black holes and jets. Based on these calculations and observational data, we conclude that dark matter and dark energy are absent in Nature and that the dynamic equations of physics at high cosmic speeds need to be refined. This is done using examples from Newton, Euler, and Klein-Gordon equations.

Keywords: Universe, cosmic observations, gravity, high-energy astrophysics, Keplerian dynamics, Newtonian mechanics, galaxies, galaxy velocity, modelling, equations, corrected Newtonian mechanics, calculations, dark matter, dark energy, black holes, jets.

Introduction. The question of the speed of cosmic bodies is key to this study. When determining the speed at which cosmic objects move, scientists determine the reference point for the calculations. For example, the speed of the Sun is known to be approximately 220 km/s if calculations are made relative to the center of the Milky Way galaxy, while the speed of Earth's orbit around the Sun is 30 km/s. On the other hand, galaxies move through space at enormous speeds, obeying the expansion of the Universe (Hubble's law). In particular, distant galaxies are receding at speeds often exceeding thousands of kilometers per second. The local rotation velocities of galaxies are significantly lower. They are determined relative to the microwave radiation filling space and are determined by local centers of gravity. In particular, the velocity of the Milky Way galaxy is approximately 600 km/s. This value is typical for many galaxies. We will focus on in this article on similar velocities, rather than the velocity associated with the expansion of the Universe.

As is well known, Newton's equations (NE) do not describe the motion of stars in galaxies, which led to the introduction of the hypothesis of the existence of dark matter (DM) [1–4]. The mass of DM in galaxies is believed to be 5–7 times greater than the mass of all visible stars and gas.

The discrepancy between NE and observations [1–4], discovered in the 1930s, is fundamental. Indeed, NE underlie all dynamic equations of modern mechanics and physics. For example, Euler's equations are a generalization of Newton's dynamic equation to the case of continuous media. However, this fundamental discrepancy still lacks a generally accepted explanation [1]. Over time, observations that contradict almost all theoretical explanations for currently known situations are accumulating [5–13]. It is becoming increasingly clear that resolving the discrepancy between Newtonian mechanics and cosmological observations requires a fundamental change in the modern mathematical picture of the world [8–16].

In [14–16], a proposal was introduced that gravity and the mass of bodies begin to depend on their velocity in space if this velocity is sufficiently high. Corresponding modifications to Newton's equations were presented in [15, 16]. These refinements resulted in a several-fold increase in the mass of observed cosmic bodies in calculations. This created gravity that explains the stability of cosmic structures despite the high velocity of their constituent bodies near the edges of the structures. As a result of taking into account the influence of velocity on mass, the agreement between the observed distribution of masses in the Universe and calculations has improved dramatically [15, 16].

However, this velocity effect has not been tested using galaxy rotation curves (see Fig. 1). For over half a century, understanding these curves has become increasingly complex.

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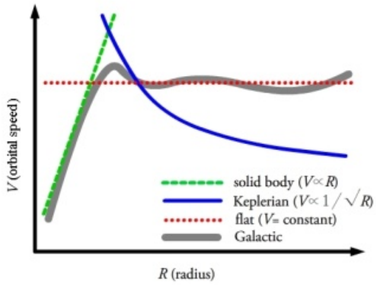

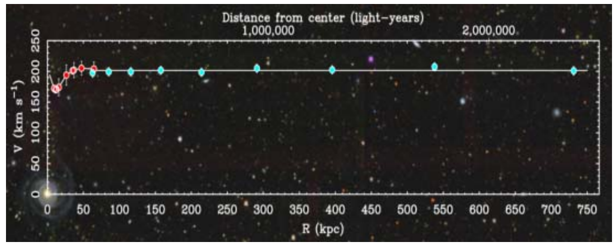

Fig. 1. Comparison of common rotation curves (solid-body, Keplerian, and flat) with a sample galactic rotation curve (Author: Lemon Balmer) https://commons.wikimedia.org/wiki/Category:Galactic_rotation_profiles?uselang=eo(left). The red dots on the right show the velocity change in the disk (central) region of the galaxy UGC 6614; the blue dots were obtained at very large distances from the disk based on lensing data [1, 10–12]

Fig. 1 (left) shows curves that qualitatively describe the situation. The green line illustrates calculations using NE. The blue curve corresponds to the Kepler model. The dark curve provides a qualitative representation of the rotation curves corresponding to cosmological observations. The red dots define a certain ideal line that defines the rotation curve of stars and their structures at very large distances from the rotation center.

On the right side of the figure is a rotation curve that initially determines the disk velocity of the galaxy UGC 6614 (red dots). The blue dots define the portion of the curve obtained using weak gravitational lensing, which allows us to study the dynamics of galaxies and their clusters at extremely large radii.

Analysis of Fig. 1 (left) shows that the continuous dark curve contradicts Keplerian dynamics and Newtonian mechanics. At the same time, this curve, qualitatively, agrees very well with the curve shown on the right side of the figure, marked by blue dots.

The discrepancies between rotation curves and calculations based on Newtonian mechanics is why the concept of dark matter was introduced [1–4]. Even relatively simple structures such as the planets of the Solar System are not described by NE. Therefore, Kepler's law and the corresponding equation (Fig. 2) are used to describe them. In general, the orbital velocities of stars and gas in various galaxies and their clusters may be in marked disagreement with the predictions of Keplerian and Newtonian dynamics. Specifically, as these structures move away from their center of mass, their velocities may not decrease, as predicted by Keplerian dynamics, but rather remain virtually constant and, sometimes, even increase (Fig. 2).

We emphasize that [14–16] were devoted to proving the absence of dark matter in space. However, they did not consider the rotation curves of cosmic structures. This publication is devoted to this consideration. It demonstrates that a refinement of NE [15, 16] allows for a qualitative description of all known rotation curves, while his classical version may be significantly inconsistent with observations. On this basis, the dynamic equations of physics are also considered and refined for cases where they are used to describe high-speed material objects.

Rotation Curves and the Fundamental Hypothesis. It should be noted here that rotation curves are a special case of many discrepancies between theoretical results in cosmology and cosmic observational data. However, this discrepancy is very important; it is the basis for the hypothesis of the existence of dark matter. This is why rotation curves deserve special attention.

Before moving on to the equations and calculations used, let us further consider the variety of rotation curve shapes. Typical ones are shown in Fig. 2.

It can be seen that the velocities of planets immediately and sharply decrease with increasing distance from the center of gravity. For galaxies, the situation is the opposite. For them, the velocity initially increases sharply, and then either continues to increase very slowly, or becomes nearly constant, or begins to slowly decrease.

We have already indicated one reason for such a strong difference in the curves for planets and galaxies. It is related to the fact that the behavior of stars in galaxies more closely resembles the behavior of particles in continuum mechanics (see the end of the article and (17)) than the behavior of point masses, namely, planets. Another reason is that planets have velocities much lower than those of stars and galaxies.

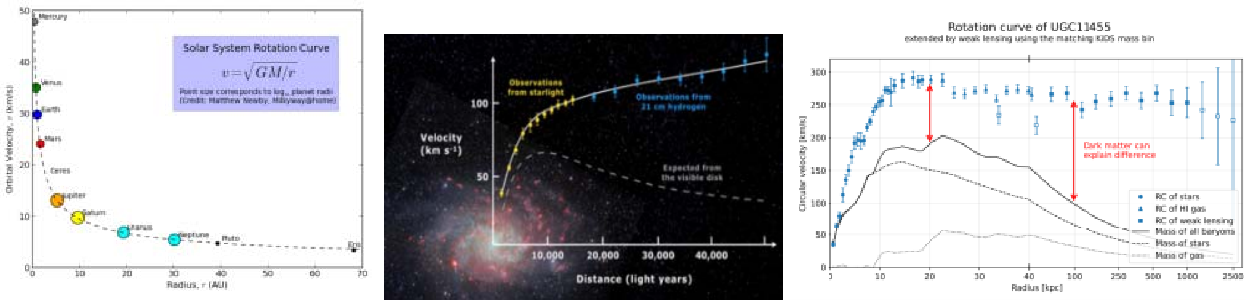

Fig. 2. A rotation curve for the Solar system is shown on the left (https://sites.temple.edu/profnewby/2019/05/04/solar-system-rotation-curve/). This "rotation curve" is "Keplerian" because it corresponds to the predictions of Kepler's laws of motion. The rotation curve of the spiral galaxy Messier 33 (yellow and blue dots with error bars) is shown in the center (https://en.wikipedia.org/wiki/Galaxy_rotation_curve). The observed rotation curve of the spiral galaxy UGC 11455 is shown on the right (curve with error bars). https://commons.wikimedia.org/wiki/Category:Galactic_rotation_profiles?uselang=eo

Familiarity with the literature on cosmic rotation curves [1–13] allows us to agree with the opinion that there are no models that correspond, even qualitatively, to all observations. Here, an attempt is made to rectify this situation. The assumption is introduced that the mass of bodies increases with increasing velocity according to the equation relating the mass of a body to its velocity. It is presented in [15, 16]. Below, it is written in simplified form.

$$m = m_0(1+v^2v_0^{-2}) \,. \qquad (1)$$

Here, m_0 is the mass of the body at rest, v_0 is a constant. The quantity $v^2v_0^{-2}$ determines the invisible mass, and m_0 is the visible mass of a cosmic object. According to [15, 16], the quantity v_0 is of the order of the velocity of the planet Mercury. It is assumed that the quantity $v^2v_0^{-2}$ in (1) has some significance only for the mass of Mercury. Indeed, as it approaches the Sun, Mercury acquires the highest velocity among the planets. We believe that velocity, albeit very weakly, begins to influence the planet's mass. Of course, other explanations exist. However, some contribution to the magnitude of Mercury's perihelion from the increase in velocity upon approaching the Sun is possible. At relatively low velocities, such as those of the planets in the solar system, the effect under consideration is almost insignificant. On the other hand, it is known that the contribution of invisible mass can account for up to 85% of the total mass of a galaxy, and the velocity of galaxies is, on average, about 200 km/s per second.

Combining all of the above, we assume in our calculations that $v_0 \approx 100$ km/s. This value is approximately acceptable for both planets and galaxies. Of course, this estimate is very, very rough. However, it correlates to some extent with data on galaxies. For example, the velocity of the galaxy ADC 252 DF2, which does not contain dark matter, is somewhere between 10 km/s and 20 km/s. However, the velocity of some galaxies can exceed 1000 km/s. For example, the velocity of the galaxy MGC 1277 is 5066 km/s. NGC 1277 has a very unusual rotation curve. It follows that the galaxy contains very little invisible matter. This is due to the fact that the velocity of NGC 1277 is possibly determined entirely by the expansion of the Universe.

Another example is the Perseus cluster of galaxies. Its recession velocity is approximately 5366 km/sec (The Perseus Cluster (also known as Abell 426) is a cluster of galaxies in the constellation Perseus). The results of a collision between two groups of galaxies in this cluster are described in [17, 18]. The collision velocity of galaxy clusters is approximately 4500 km/s. After the collision, the resulting heated gas, which makes up the bulk of visible matter in colliding groups, remained at the collision site. Its velocity is approximately 10 km/s. The behavior of this gas is ideally described by the Newtonian model. Thus, it was sufficient for the clusters to lose velocity, and the need for dark matter disappeared. On the other hand, "dark galaxies" have recently been discovered. These are objects that, according to [19], are more than 99% composed of dark matter (galaxy CDG2).

Basic Formulas, Calculation Examples, and Their Analysis. Now we will describe the main features of the rotation curve shapes shown in Figs. 1 and 2 based on the refined Newton equations (14) and (15).

We will consider only rotational motions close to circular. In this case, we have Newton's second law and the centripetal acceleration of the galactic element. Considered together, they yield $F(r) = m(r)v^2 / r$. Next, we use relations (1). As a result, we obtain a refinement of Newton's equation that takes into account the effect of the velocity of a cosmic body on its visible mass $m_0(r)$,

$$F(r) = m_0(r)(1+v^2 v_0^{-2})v^2 / r. \tag{2}$$

The positive solution of this equation with respect to v has the form

$$v = v_0[-0.5+0.5\sqrt{1+4rv_0^{-2}F(r)/m_0(r)}]^{0.5}. \tag{3}$$

Here and above, $F(r)$ is the gravitational force, and r is the radial coordinate. We have presented the basic relation (3), which will be used below. The difficulty in applying it is that the parameters included in it $F(r)/m_0(r)$ and v_0 are generally unknown. Above, we assumed that $v_0 = 100$ km/s. Now we will consider $F(r)/m_0(r)$. Let it vary in (3) around a constant value A. In this case, (3) reduces to the following calculation formula:

$$v = 100(-0.5+0.5\sqrt{1+4Ar/10000})^{0.5}. \tag{4}$$

Here r is measured in light years and, in our calculations presented below, reaches two million. The introduced estimates of the quantities $F(r)/m_0(r)$ and v_0 allow us to begin the calculations.

Fig. 3 shows the velocity calculations according to (4), with and without accounting for the invisible mass of moving objects. The curves on the left define the initial sections of the curves. The curves on the right are the same curves, but calculated up to a distance of one and a half million light years from the center of rotation. Four options are considered: A = 2, 1, 0.5, or 0.01. The curves found with the invisible mass included are plotted as a solid line; the dotted curves determine velocities taking into account only the visible mass.

It is clear that the contribution of the invisible mass significantly reduces velocities found according to the classical Newtonian equation (that is, assuming that $v^2 v_0^{-2} = 0$ in (2)). For the case of A = 2, the differences in velocities obtained by different algorithms are greatest, reaching a factor of 4 (curves on the right).

Overall, the results of calculations performed over a very narrow range of A cover, in terms of velocity amplitudes, a very wide range of rotation curves found by the authors in the relevant literature. The shapes of the curves on the left qualitatively correspond to the initial sections of many rotation curves. In particular, the curve calculated for A = 2 (on the left) describes the rotation curve of the galaxy Messier 33 well. A combined examination of the curves shows that the initial sections of rapid velocity change (solid curves), then transition to sections of very slow velocity increase (solid curves). That is, they correspond to the well-known "flat" region of many rotation curves found for galaxies. Some of these are shown in Figs. 1, 2, and 4. All of the above indicates that the range of variation of $F(r)/m_0(r)$, as well as v_0, are generally chosen correctly.

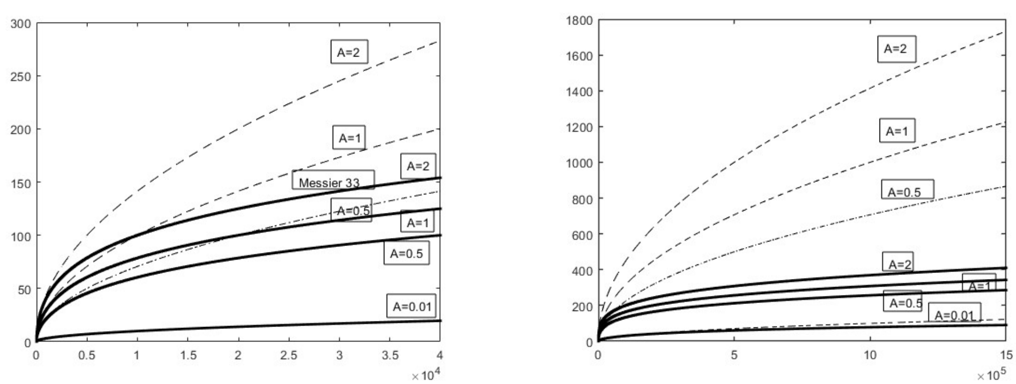

Fig. 3. Comparison of rotation curves calculated with (solid curves) and without (dashed curves) the invisible mass according to (4). The upper solid curve in the figure on the left corresponds to the spiral galaxy Messier 33 (see the center of Fig. 2)

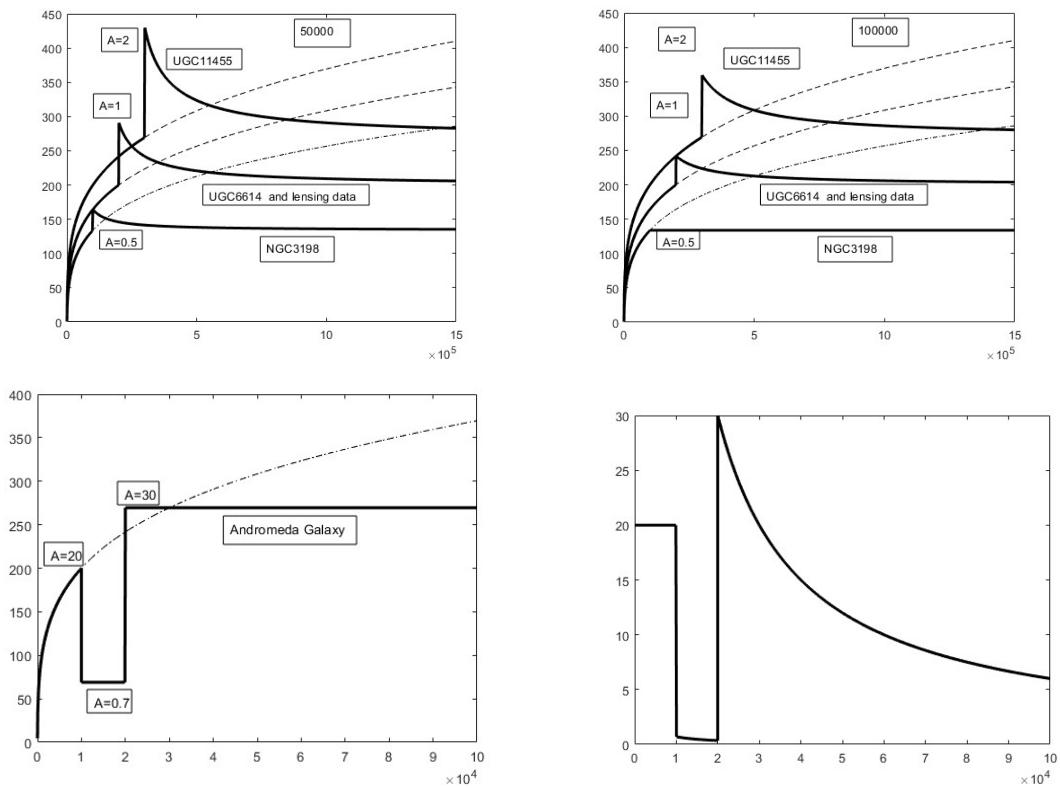

Fig. 4. Rotation curves calculated according to (4) and (5) for Δ = 50000 (left) or 100000 (right) (upper row). The rotation curve calculated for Andromeda Galaxy is presented on the left. The function $F(r)/m_0(r)$ for it is presented on the right (bottom row). Numbers and inscriptions indicate calculation parameters and correspond to curves of galaxies

Thus, the assumption that the value of $F(r)/m_0(r)$ can be approximately constant was justified. Of course, it varies for different galaxies. Another important result, following from Fig. 3, is the decrease in the magnitude of the invisible mass as the ratio $F(r)/m_0(r)$ decreases. For example, at A = 0.01, the invisible mass has virtually no effect on the velocity, that is, it is practically nonexistent. Thus, if the influence of the visible mass $m_0(r)$ is much greater than the influence of the gravitational force $F(r)$, the influence of the invisible mass on the galaxy's rotational velocity disappear.

Accounting for the Continuum Effect. However, some success of the above calculation does not preclude refinement of its algorithm. Newton's equations are written for point masses. There is no doubt that, in principle, it is more correct to study the motion of stars in galaxies based on the equations of continuum mechanics. Therefore, following the continuum hypothesis, we will further consider a certain "small" part of galaxies. We will assume it to be approximately one-dimensional directed along the radius. It has one light-year in length. We will consider this volume as a "point." In our study, this "point" moves away from the center of the galaxy, changing its velocity and conserving mass. The gravity acting on this "point" changes. Let us consider qualitatively the changes in these quantities and corresponding consequences. Further, we will refer to the "point" as an element. The interaction of the moving element with surrounding stars (i.e., the surrounding environment) is undoubtedly crucial. But how can this interaction be taken into account throughout the element's motion beyond the galaxy? In our analysis, we will distinguish two stages of this motion.

The first stage is determined by the time the element moves within and near the disk (center) of the galaxy. During this interval, the element moves within the source of gravity itself, and the element's density decreases. We will assume that gravity and density change such that their ratio, to some approximation, remains constant. Namely, the element's velocity should undoubtedly increase for some time, since the bulk of the galaxy's mass is located beyond the distance the element has reached. At this stage, the element's rotation curve differs fundamentally from the dynamics of the rotation curves of the planets closest to the Sun (Fig. 2). Indeed, in the initial sections, the galactic rotation curves increase rapidly. Only after this section does the curve's growth begin to slow (Figs. 1–3). Based on the above, we can assume that velocity expression (4) remains applicable at the centers of galaxies even at this study.

As the element moves away from the center of the galaxy, it enters conditions for the solar system's outermost planets. That is, the change in the element's velocity almost vanishes. The element's rotation curve becomes increasingly "flat," resembling the behavior of the outermost planets in the solar system (Fig. 2). To describe this beyond the disk, we assume that gravity decreases quadratically with distance from the disk, according to Newton's gravitational model. At the same time, the initial mass of the element must remain constant, although the galaxy's density beyond its disk begins to decrease significantly. We satisfy this constancy condition by assuming that beyond the disk, the element's length increases proportionally to density decrease (as result the length increases).

Given the above, we assume that beyond the disk:

$$F(r)/m_0(r) = A[r_1/(r - r_1 + \Delta)]. \qquad (5)$$

Here r_1 is a certain distance from the center, where the disk ends and the galaxy's periphery begins. The constant Δ serves to smooth out the velocity during the transition from the disk to the periphery.

The calculations presented in Fig. 4 used formula (3), where $F(r)/m_0(r) = A$ inside the disk and expression (5) outside the disk. The magnitude of Δ was 50,000 (left) and 100,000 (right). The magnitude of A was 2, 1, and 0.5. Note the jumps present at the beginning of the curves. Interestingly, they were observed in the rotation curves of some galaxies (see Fig. 5).

The proposed algorithm for constructing curves can be substantially generalized to describe virtually all rotation curves. In this case, considering the disk, we assume

$$F(r)/m_0(r) = A\tanh \alpha r \text{ and}$$

$$v = v_0(-0.5 + 0.5\sqrt{1 + 4rv_0^{-2} A \tanh \alpha r})^{0.5}. \qquad (6)$$

Here α is an arbitrary constant chosen to best describe the initial portion of the rotation curve.

At the discontinuous points and outside the disk, the refinement algorithm is carried out according to the following expression:

$$v = v_0(-0.5 + 0.5\sqrt{1 + 4rv_0^{-2} A \tanh \beta[r_1/(r - r_1)]})^{0.5}. \qquad (7)$$

Arbitrary constants A, α, β and r_1 included in (6) and (7), when appropriately chosen, allow a more detailed description of the rotation curves of cosmic systems than (4). Examples of calculated initial portions of the curves are shown in Fig. 6 (left). It was assumed that α = 0.002, 0.0008, 0.0005, and 0.0001 (dashed curves). Remarkably, the curve for the 0.002 case practically coincides with the case for $F(r)/m_0(r) = 1$ (solid curve) (upper row).

The calculation parameters are shown in the figures. They correspond to those shown in Figs. 3 and 4. Numbers and inscriptions indicate calculation parameters and correspond to curves of galaxies. The dashed portions of the curves were calculated without taking into account the invisible mass. The results of calculations based on (6) and (7) are shown by solid black lines. They take into account the invisible mass. It is easy to see that these curves are similar the curves in Fig. 4 outside the jump zones.

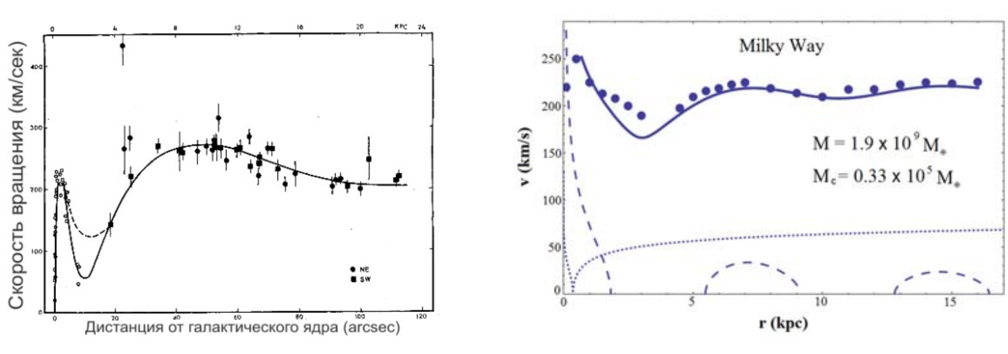

Fig. 5. Examples of jumps in velocity change in galaxy rotation curves. Rotation curve of the Andromeda Galaxy (left). Rotation curve of the Milky Way Galaxy (right). https://commons.wikimedia.org/wiki/Category:Galactic_rotation_profiles?uselang=eo

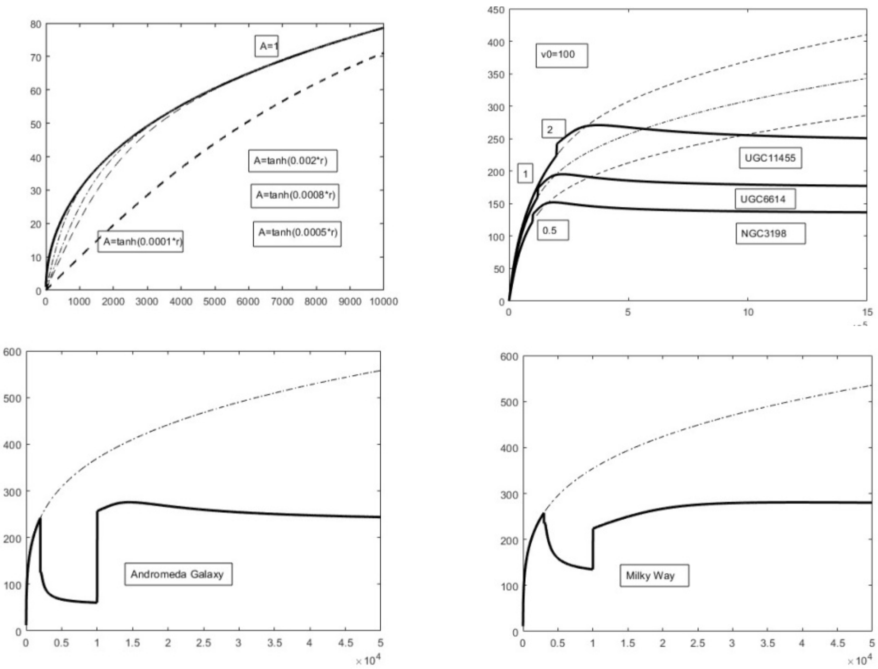

Fig. 6. Initial portions of the curves calculated using (6) (left, upper row). Rotation curve shapes found using (6) and (7) (upper and bottom rows)

In conclusion of this section, we note that, qualitatively, the shapes of all the refined curves (Figs. 4–6) correspond to the simplest calculation presented in Fig. 3. It follows that the use of the refined Newtonian equation (2), which takes into account (1), is a mandatory and necessary condition for the agreement of the calculations with the observed rotation curves.

Dark energy and the estimate of the energy of the Universe. Dark energy (DE) is a hypothetical form of energy that uniformly fills the entire space of the Universe and is responsible for its accelerated expansion. In modern cosmology, it accounts for approximately 68–73% of the total mass and energy of the Universe.

In [16], it was shown that accounting for the dependence of the mass of cosmic bodies on velocity allows us to reject not only the dark matter hypothesis but also the hypothesis of the existence of DE. We develop some results presented in [16].

Formula (1) and corrected Newton's equations instead Dark Energy. We will use the most general and, at the same time, extremely simple expression for the energy of a point mass

$$E^2 = m^2 v^2 c^2 + m_0^2 c^4. \qquad (8)$$

Here, E is the energy, c is the speed of light. It clearly follows from (8) that the mass of a body is related to its velocity. A somewhat different relationship is determined by the relation

$$m = m_0 (1 - v^2 c^{-2})^{-0.5}. \qquad (9)$$

Thus, according to (9), the mass of a body changes only at velocities very close to the speed of light, that is, practically only for elementary particles. However, according to the theory being developed, the mass of cosmic bodies moving at high velocities, which are at the same time many orders of magnitude less than the speed of light, also depends on velocity (1). In [16], it is assumed that the change in mass described by formula (9) can influence the overall change in the mass of cosmic bodies and, through this influence, the global energy of the Universe. Therefore, the need to introduce the DE hypothesis disappears.

Using (1), formulas (9) and (8) were transformed to the forms

$$m = m_0[1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}], \qquad (10)$$

$$m = m_0[(1 - v^2 c^{-2})^{-0.5} + v^2 v_0^{-2}], \qquad (11)$$

$$(E / cm_0)^2 = [1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}]^2 v^2 + c^2. \qquad (12)$$

We further assume that $v^2 c^{-2} << 1$ and also that $2v^4 v_0^{-2} << c^2$. In this case, (12) yields

$$E^2 \approx (cm_0)^2 (v^6 v_0^{-4} + c^2). \qquad (13)$$

This shows, approximately, that the energy depends only on the velocity of the object. For sufficiently low velocities, expression (13) reduces to a special case following from (8). However, for sufficiently high velocities of cosmic structures, the term $v^6 v_0^{-4}$ can be equal to or even exceed the term c^2. Let us consider the cases of different velocities in space, taking v_0 = 100 km/s and $c \approx 3*10^5$ km/s. We will consider the case of v = 200 km/s, corresponding qualitatively to the velocity of stars; the case of v = 600 km/s, corresponding qualitatively to the velocity of galactic clusters; and v = 1000 km/s, which some researchers attribute to the velocity of the entire observable Universe.

In the first case, we obtained that $(E / cm_0)^2 \approx 5*10^5 + c^2$. In this case, the contribution of the energy of the cosmic velocity under consideration to its total energy is very small compared to c^2.

Let v = 600 km/s. In this case $(E / cm_0)^2 \approx 5*10^8 + c^2$, the contribution of the energy of the considered velocity of space to its total energy becomes noticeable compared to c^2.

Let v = 1000 km/s. In this case $(E / cm_0)^2 = 10^{12} + c^2$, the contribution of space velocity to its total energy becomes overwhelming. It exceeds all other contributions by more than three times.

This result was obtained with quite realistic parameters of the model used. It agrees with observations and, at the same time, completely contradicts the DE hypothesis, which is intended to satisfy observations, and it completely satisfies them, yet its existence is in no way explained.

Observations indicate that imperceptible energy constitutes almost 80% of the entire universe. It follows from this that, on average, all bodies in the universe move at a speed slightly exceeding 1000 km/s.

Now we can begin to explore how changes in mass (10), (11), and energy (12) affect the equations of motion of bodies. This problem will be considered in Section 6. Here, we will focus only on refining Newton's equations. They will take into account the change in mass according to (10), that is, they will be valid for velocities close to the speed of light. A refinement of Newton's equations for non-light velocities of bodies was carried out in [15, 16].

If we accept (10), then the law for gravitational force F, which relates the acceleration a of an object to its velocity v, is postulated as follows

$$F = m_0[1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}]a. \quad (14)$$

If $v = 0$, then the given formula coincides with Newton's result written for a point mass.

Now let us turn to Newton's law of gravitation written for cosmic bodies moving at high speeds. Bodies are considered as points with masses M_1 and M_2 at rest. Taking into account (10), we write the law as follows:

$$F_{12} = g m_1 m_2 / r^2,$$
$$m_1 = M_1[1 + v_1^2 v_{10}^{-2}(1 - v_1^2 c^{-2})^{-0.5}],$$
$$m_2 = M_2[1 + v_2^2 v_{20}^{-2}(1 - v_2^2 c^{-2})^{-0.5}]. \quad (15)$$

Here g is the adjustable constant, r is the distance between the points, v_1, v_1 are the velocities of the corresponding bodies, v_{10} are v_{20} constants. If $v_1 = 0$ and $v_2 = 0$, then (14) yields Newton's equation of gravity.

The presented analysis opens the way to a new understanding of the contribution of the velocity of cosmic bodies to the energy of the Universe. This issue was explored to some extent in the previous sections, where the rotation of galaxies was examined. Equations (14) and (15) open the way to studying the influence of the motion of bodies with near-light speeds on dynamic processes in the Universe.

Rotational Dynamics of Black Holes and Jets. The velocity of galaxies is typically much slower than the speed of light, and therefore the contribution of near-light velocities to the galaxy's rotation curve is usually negligible [20]. However, the range of velocity variations of bodies in space is very wide and includes the motion of very large bodies at near-light speeds [21–25]. Traditionally, the motion and interaction of cosmic bodies in these regions is studied using continuum equations. However, in this study, we are more interested in the underlying foundations of our understanding of Nature than in the accuracy of the calculations themselves. An intriguing question is what picture of Nature will emerge from a direct study of situations where bodies move at near-light speeds. Such cases include the motion of bodies near black holes located at the centers of galaxies or bodies falling into black holes.

Rotating black holes are located at the centers of many galaxies. As they rotate, they capture the surrounding medium, creating a rotating accretion flow. The flow velocity approaches the speed of light at the edge of the black hole. Powerful jets of matter perpendicular to the plane of the flow can emerge there. Some details of the formation of such jets remain beyond astronomers' understanding.

For example, how is the accretion flow velocity related to the formation of the jets? Do they originate in the center of the hole's disk or at its edge? What are the jet dynamics?

Of course, we have no way to answer the questions posed by experts. What primarily draws us to the problems of black holes is that the circular rotation pattern of the hole and the flow resembles the model we used to examine the rotation curves of galaxies. It is interesting to see what the approach developed for rotating galaxies will yield when applied to rotating black holes and accretion flows?

We attempt to implement this idea below using refined Newtonian equations.

We will consider only rotational motions close to circular. In this case, we have Newton's second law (14) and the centripetal acceleration of an element of orbital matter v^2/r. Let's consider them together. We write the resulting equation as follows:

$$F/m_0 = [1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}]v^2/r. \quad (16)$$

Based on this equation, we will conduct a rough, model study of the effect of orbital velocity on the gravitational force-to-mass ratio F/m_0. Specifically, we will consider the dependence of the magnitude of F/m_0 on the orbital flow velocity for black holes and quasers. In our calculations, we assume that inside the black hole disk, the velocity increases linearly $v = Ar$, while outside the disk, the velocity decreases linearly $v = A/r$. The computational domain is a circle with a radius of 500 light seconds. This quantity is on the order of the size of many black hole disks.

It is known that the flow velocity can be converted into radiation. Many accreting black holes form narrow relativistic jets ejected along the rotation axis. Fig. 7 provides a general idea of the described situation. The same figure shows a series of curves of the values F/m_0 calculated for different A.

Calculations were performed for A = 800, 900, 2500, 3000, and 20.000. The value of F/m_0 increased by 13 orders of the magnitude. The calculations showed that increasing velocity leads to a concentration of F/m_0. It is clustered in the vicinity of a region (a circular ring) where the flow velocity reaches the speed of light. As A increases, this region (ring) tends to collapse to a point. Moreover, as the disk is approached, the value of F/m_0 increases rapidly, but inside the disk F/m_0 becomes negligibly small compared with F/m_0 outside of the disk.

We emphasize that the jump in the curve in the figure occurs where $v = c$. Apparently, the jump determines the radius of the disk. The jumps are stationary at a fixed A. The arrows in Fig 7 only show the direction of the hole's collapse as A increases. It can be assumed that if A changes periodically, pulsating jets arise.

We do not expect Fig. 7 to describe any reality. We performed the calculation, as an example of using Newton's refined equations to calculate bodies moving at speeds close to the speed of light.

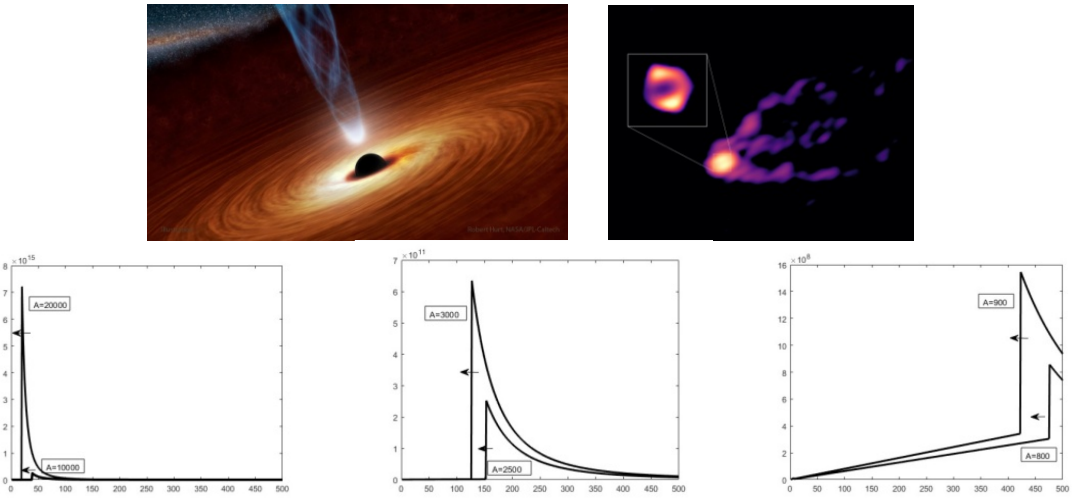

Fig. 7. Artist's conception of a rotating black hole and the black hole's shadow at the center of the galaxy Messier 87 (M87). There, matter can reach orbital velocities equal to the speed of light. A jet of matter and energy can erupt in a direction perpendicular to the central disk (left, top row). The curves qualitatively show how increasing velocity changes the value of F/m_0

We can interpret the curves in the figure as describing the emergence of a thin-walled cylindrical jet (radiation jet) of F/m_0. The radius of this jet decreases, and its intensity increases very rapidly with increasing flow velocity A.

Overall, the picture emerging from the calculations is consistent with the data of the upper row (Fig. 7).

Astrophysical jets are extreme phenomena in the Universe [21]. Despite a century of research, the connection between black hole physics and the processes underlying the formation and launch of these jets remains unclear. Here, we present a physical picture derived from our refined Newtonian equation.

Relativistic jets are found to propagate along the rotation axis of the black hole that launches them. Importantly, the jets are shaped like hollow cylinders. They are ejected from the portion of the accretion orbital flow where its velocity approaches the speed of light.

Dynamic Equations of Continuum Mechanics and Scalar Fields. Newton's dynamic equation is the starting point for deriving all dynamic equations of continuum mechanics. On the other hand, the mass-energy equivalence equation (8) is one of the fundamental equations in physics. However, these equations may not be valid when applied to cosmology. This was demonstrated above. Therefore, it was in cosmology that the hypothesis of the existence of dark matter (DM) and DE arose. It was during the analysis of cosmological data that the suspicion arose that the mass of observed objects did not correspond to their observed mass, which led to the hypotheses of DM and DE. In contrast, the assumption of the dependence of mass on velocity was introduced [14–16], which immediately resolves cosmological problems and eliminates the need for DM and DE. In particular, taking (1) into account leads, as in the case of Newtonian mechanics, to the need to refine many equations of mathematical physics.

Euler equations. Hydrodynamic equations are often used to model the high-speed motion of gases, particles, and even clusters of stars and galaxies. It follows from the above that they must be refined. As an example of such a refinement, consider Euler's equations [22] written using (1) for the mass of a unit volume of fluid. In this case, we have

$$\mathrm{d}\overline{\mathrm{v}} / \mathrm{d}t = -\nabla p / \rho_0[1+(\overline{v} / v_0)^2] + \overline{\mathrm{g}}. \qquad (17)$$

Here the dash over the letter defines the vector, t is time, p is pressure, ρ_0 is density of the visible substance, and $\overline{\mathrm{g}}$ is gravitational acceleration. For simplicity, we assume the fluid is incompressible. Then

$$\mathrm{div}\overline{\mathrm{v}} = 0. \qquad (18)$$

We have presented some of the simplest equations of fluid motion. But it can be further simplified if $(\overline{v} / v_0)^2 << 1$. In this case, it reduces to Euler's equations, which he derived in 1753 (published in 1757).

Obviously, introducing (1) into Euler's equations increases the level of nonlinearity in the equations of motion. This is entirely consistent with the results of introducing (1) into Newton's equation of motion. There, the level of nonlinearity increased from quadratic to the fourth power (2).

We are particularly interested in the problem of fluid rotation. In this case, equation (13) can be represented in a form that takes into account the centrifugal force [26]:

$$\mathrm{d}\overline{v} / \mathrm{d}t + 2\overline{\Omega}\overline{v} = -\nabla P / \rho_0[1+(\overline{v} / v_0)^2]. \qquad (19)$$

Here we set $\overline{\mathrm{g}}$=0, $\overline{\Omega}$ is the angular velocity vector of the fluid rotation, and $P = p - \frac{1}{2}\rho(\overline{\Omega}\overline{r})^2$. We will consider steady-state motions, when $\mathrm{d}\overline{v} / \mathrm{d}t$=0 [22] and the case of plane flow, when the axial coordinate is not taken into account. Then, from (19) it follows that

$$2\Omega v_y = -\tfrac{\partial P}{\partial x} / \rho_0[1+(\overline{v} / v_0)^2],$$

$$2\Omega v_x = -\tfrac{\partial P}{\partial y} / \rho_0[1+(\overline{v} / v_0)^2]. \qquad (20)$$

Here x and y are Cartesian coordinates in the plane perpendicular to the rotation axis. Subscripts denote the components of the velocity vector along the corresponding coordinates. For simplicity, we assume $(\overline{v} / v_0)^2$ =0. From the above, it is clear that

$$\tfrac{\partial v_x}{\partial x} + \tfrac{\partial v_y}{\partial y} \approx 0. \qquad (21)$$

In our opinion, the last expression explains why, in a region sufficiently distant from the galactic disk, the rotation curve becomes "flat." There, the velocity components of stars, which can be considered as particles of the galactic fluid, can be linearly variable. Moreover, these components can be constant. This corresponds to the "flat" sections of the rotation curves, which are present in both cosmological observations and calculations (see Figs. 1–6).

Klein-Gordon Equation. The Klein-Gordon equation is one of the most well-known equations of relativistic quantum mechanics. It is also used in cosmology. Therefore, it makes sense to derive it in this article, taking into account the effect of velocity on the apparent mass. We will start from (11):

$$E^2 = (cm_0 v)^2[1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}] + m_0^2 c^4. \quad (22)$$

We assume that $p = m_0 v$. Next, we derive a version of the Klein-Gordon equation, based on (22). We introduce the wave function of a certain scalar field. For the wave function, following [27], we introduce the following relation:

$$\phi = \phi_0 \exp[-i(px - Et)/\hbar]. \quad (23)$$

Differentiating this function yields:

$$\phi_{xx} = -p^2\hbar^{-2}\phi \text{ and } \phi_{tt} = -E^2\hbar^{-2}\phi. \quad (24)$$

We enter the values E and p found from this into (22) and obtain:

$$-\phi_{tt}\phi^{-1}\hbar^2 = -\phi_{xx}\phi^{-1}\hbar^2 c^2[1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}] + m_0^2 c^4. \quad (25)$$

The desired equation with respect to φ is written as follows:

$$\phi_{xx}[1 + v^2 v_0^{-2}(1 - v^2 c^{-2})^{-0.5}] - c^{-2}\phi_{tt} - \hbar^{-2} m_0^2 c^2 \phi = 0. \quad (26)$$

If $v^2 v_0^{-2} = 0$, then (26) reduces to the traditional, linear Klein-Gordon equation. Numerous examples of the use of the nonlinear version of this equation when considering various problems can be found in [14]. In particular, the Galiev-Galiyev model [14, 16], which describes the birth and initial development of our Universe, is constructed using the nonlinear Klein-Gordon equation.

Cosmic processes are accompanied by a huge variety of emerging velocities. Equations (14) and (26) and their obvious generalizations may allow us to discover new effects arising from the high-speed motion of media and fields in the Universe. We hope the reader has seen an example of such possibilities in the refined Newtonian equation of motion (2) and presented above analysis.

Conclusion. This article is a final one based on the material presented in two fundamental papers [15, 16] and a book [14]. In it, we focus on comparing theoretical data following from the general theory with the results of cosmological observations.

We have completed the construction of a new picture of the physical world, distinct from the existing one (the modern cosmological model (Lambda – CDM)). It includes, as a component, a new theory of gravity. Its essence is that gravity is the result of the motion of a body or elementary particle. As they move, they distort space-time (according to the general theory of relativity) or distort the Fundamental Background [14]. This distortion, or even destruction, is perceived as gravitation. Without motion, there is no gravity. Here it must be emphasized that absolutely motionless media and bodies do not exist in Nature. Everything moves relative to something. Even human bodies consist of an infinite number of moving elementary components, the vast majority of which have enormous speeds. A new understanding of gravity and the resulting assumption (1) (see also (10)–(12)) eliminate the need to introduce so-called dark matter and dark energy into cosmology.

However, assumption (1) has not yet been tested using examples of rotation curves of cosmic bodies. A significant portion of this article is devoted to this test. It is shown that fundamental assumption (1) allows for the description of various rotation curves, including those that cannot be described by other theoretical models. Using examples of rotation curves, it is demonstrated that the presented refinements to Newton's equations are necessary for a more accurate description of the motion of cosmic bodies and systems. It is emphasized that assumptions (1), (10)–(12) not only clarify the general picture of the world order but can also be useful in studying the motion of various continuous media and various scalar physical fields.

Final remark. The calculation results are highly dependent on the constant v_0 in (1). This constant is chosen so that the theory describes both the motion of planets and galaxies and clusters of them. The value v_0 = 100 km/s was chosen as a compromise for describing both the planets of the Solar System and the Milky Way galaxy.

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КРИВЫЕ ВРАЩЕНИЯ, ГРАВИТАЦИЯ, МАТЕРИЯ, ЭНЕРГИЯ, УРАВНЕНИЯ НЬЮТОНА И ДВИЖЕНИЯ В КОСМОЛОГИИ

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Рассматриваются тела, движущиеся с очень высокой скоростью. В этом случае масса этих тел зависит от скорости. Используя это, моделируются кривые вращения галактик и их скоплений. Скорости, близкие к скорости света, рассматриваются на примерах черных дыр и струй. На основе расчетов и данных наблюдений делается вывод об отсутствии в природе темной материи и темной энергии и о необходимости уточнения динамических уравнений физики при высоких космических скоростях. Это делается на примерах уравнений Ньютона, Эйлера и Клейна-Гордона.

Ключевые слова: Вселенная, космические наблюдения, гравитация, высокоскоростная астрофизика, кеплеровская динамика, ньютоновская механика, галактики, скорость галактик, моделирование, уравнения, скорректированная ньютоновская механика, расчеты, темная материя, темная энергия, черные дыры и струи из них.