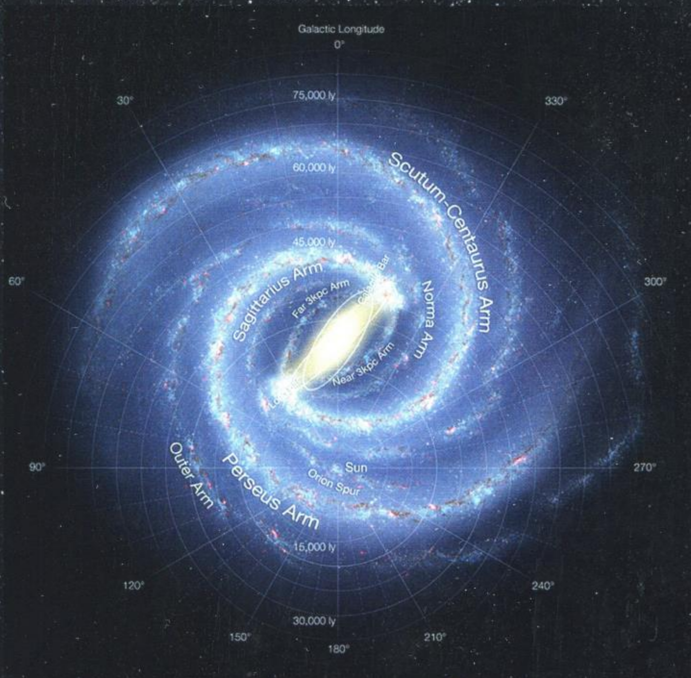
V. Leiman

THE MODIFIED BASICS OF COSMOLOGY

GALAXIES



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The ubiquitous presence of a special form of matter – the World Substance is assumed, which is continuous and thus creates space where our Universe was formed as follows.

The world substance has a gravitational component. The Big Bang resulted in the creation of the “Dark Matter” areas dense with positive gravity in the form of “filaments”, and in the formation of cylindrical vortices of Dark Matter. Dark Matter density fluctuations occurred in the areas with high Dark Matter concentrations, including in vortices. In critical Dark Matter density fluctuations phase transitions occurred with the emergence of ordinary matter from Dark Matter in the form of voluminous, high-temperature plasma formations — plasmoids, consisting of primary particles of ordinary matter and radiation. Later, plasmoids formed galaxies – both elliptical as well as spiral from those within the vortices.

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CONTENTS

1. THE MODIFIED BASICS OF COSMOLOGY

The paper discusses the nature of space and the birth of the universe. It assumes the ubiquitous presence of a special form of matter – the World Substance, which constitutes continuum and thus creates the dimension where our Universe exists. The world substance is absolutely transparent for the movement of ordinary matter elements due to the presence of a large energy barrier preventing the interaction of ordinary matter with the world substance. The world substance has a gravitational component, which in the course of the Big Bang led to the creation of the areas dense with positive gravity (Dark Matter) and the areas with negative gravity spaces (Dark Energy). When Dark Matter condensed into large-scale concentrations in the form of filaments, Dark Matter vortices were also created. Galactic-scale dark matter density fluctuations were happening everywhere. Within the critical dark matter fluctuations phase transitions occurred, where ordinary matter was created from Dark Matter taking the form of voluminous, high-temperature plasma build-ups - plasmoids, consisting of ordinary matter elementary particles and radiation. After cooling, the plasmoids turned into gaseous accumulations of hydrogen, helium and lithium, and the radiation spread through space in the form of Cosmic Microwave Background. Later the gaseous accumulations formed star clusters – or galaxies.

Key words: world substance, continuum, dark matter, dark energy, big bang, dark matter condensations, filaments, phase transition, plasmoids, galaxies.

1. INTRODUCTION

According to the standard cosmological theory parametrizing cold dark matter and constant Λ (Lambda Cold Dark Matter - ΛCDM), our Universe consists of several types of matter / energy (Dolgov, 2014). Only 5% of all matter is occupied by ordinary baryonic matter, of which galaxies and interstellar dust are composed. A large proportion is occupied by two yet unknown forms of matter/energy – dark matter (Dark Matter-DM) (approximately 27%) and dark energy (Dark Energy-DE) (approximately 70%). In addition, Cosmic Microwave Background Radiation (CMB) and neutrinos are ubiquitous, making up a negligible fraction of the total mass of the universe. With that, the average density of matter in the universe is close to critical $\rho_{tot} \approx \rho_c$, (ρ_c= 0.85 10^{-29}g·cm^{-3}), and the space of the universe has a flat Euclidean geometry.

It is also known that our universe is constantly expanding. The expansion is currently accelerating. Its rate is proportional to the distance between the observed points of the universe. The proportionality factor is *H* (Hubble constant).

The ΛCDM standard cosmological theory's description of the cosmological history and the evolution of the universe (which includes the Inflation and the Big Bang theory) is reasonably good – from the universe's inflation and the Big Bang to the present day. However, its description also contains several blank spots, which, among other things, lead to the serious difficulties when explaining the structure of galaxies and their formation.

One of these "spots" is the problem of cosmological coincidences (concordance) or, as they are sometimes called, cosmic conspiracy – that is, the similarity in size of absolutely different and, according to ΛCDM, unrelated forms of matter / energy: baryons, dark matter and dark energy (Dolgov, 2014). The reason for this similarity is still unknown.

Below are the modern cosmological parameters of the main forms of matter in the universe (relative densities in fractions of % from ρ_c, as well as the value of the constant H) (Dolgov, 2014):

$$H = (67.9 \pm 1.5)\ \text{km/s}^{-1}\text{Mpc}^{-1}, \quad (1)$$

$$\Omega_b = 4.9, \quad (2)$$

$$\Omega_{DM} = 26.8, \quad (3)$$

$$\Omega_{DE} = 68.3. \quad (4)$$

One can find more about the achievements and unresolved issues of modern cosmology in the reviews and the monographs (Cherepashchuk, 2013; Turner and Tyson, 1999; Weinberg, 2008; Gorbunov and Rubakov, 2008, 2010).

Recent astronomical research has introduced more white spots to the ΛCDM theory. An unexpectedly high concentration of protogalaxies with measured redshift of z > 4 was detected in deep space (Wang et al. 2019, Steinhardt et al. 2016). The number of massive galaxies with measured redshift of z > 4-10 is several orders of magnitude larger than predicted by calculations (Mueller et al. 2018). It is evident, that there is a much faster galaxy formation mechanism, than the one, described by the ΛCDM theory. These observations question the ΛCDM theory-proposed mechanism, where the galaxies are believed to be formed by the stars and gases accumulating in dark matter filaments.

On the other hand, a detailed study of the nearest three spiral galaxies (Milky Way, Andromeda, and Centaurus A) revealed extensive polar structures of satellite galaxies, the motion of which also does not agree with the ΛCDM theory predictions (Mueller et al. 2018). The presence of non-spherical structures of satellite galaxies in nearby spiral galaxies rotating coaxially around the main galaxy poses another question for the ΛCDM theory. In particular, it challenges the formation model of the ordinary matter structures at the subgalactic scale. In most cases, the ΛCDM model expects a close to isotropic distribution and random kinematics for galactic satellite systems. Thus, the question arises about the need to revise the ΛCDM theory, but already the evolution of galaxies.

This article proposes the Modified Basics of Cosmology (MoBC) theory, which discusses the nature of space, its continuum, and also explains the mechanisms of galaxy formation, the reasons for the rotation of spiral galaxies and the formation of their arms.

2. EMPTINESS

Aristotle (Aristotle, 1981) and Descartes (Descartes, 1989) gave a number of assessments and provided numerous evidences that it is impossible for the emptiness (an empty space) to exist. Descartes describes emptiness as “when there is nothing”, i.e., simply “nothingness” (Descartes, 1989, p. 351). If we are to delve into more detail, then it is important to understand, that “nothingness” not only contains nothing, but by definition also does not have size. This means that “nothingness” does not exist in nature! Consequently, emptiness, which contains nothing, does not have extension (or size) and therefore it also does not exist in nature.

On the other hand, there is a physical reality – space. Aristotle defined space as a "place" where four tangible elements can exist: earth, water, air and fire (Aristotle, 1981, p. 123). Aristotle also speaks about "ether" – a ubiquitous, all-pervading "first body" (Aristotle, 1981, p. 272). Newton defined this physical notion as a stationary, empty "absolute space" (Newton, 1989), Einstein – as a "physical space" (Einstein, 1965, 1966). Authors Arkhangelskaya, Rosenthal and Chernin in their work (2006) use the "physical vacuum" definition for space. Chernin in his work also mentions "space vacuum" (Chernin, 2001).

Attempts to find sings of the ether's existence persisted from the very appearance of its hypothesis. The complete absence of the ether's influence on the movement of light was experimentally proved (Michelson and Morley, 1887). Due to the results of Michelson and Morley experiment, Einstein considered the space without ponderable matter and radiation to be empty and deemed the ether hypothesis obsolete up until 1910 (Einstein, 1985, p. 138). In his article "Ether and the Theory of Relativity", published in 1920, Einstein put forward a hypothesis about "gravitational ether" (Einstein, 1985, p. 138), that is, the gravitational field of ponderable matter creates space with its metric properties. However, many years later, in 1952, Einstein agreed with Descartes that the existence of empty space is out of the question. '…There is no such thing as an empty space, i.e., a space without field. Space-time does not claim existence on its own, but only as a structural property of the field' (Einstein, 1986, p. 758). Thus, he believed that the metric of space is created by the gravitational field of ponderable matter.

Subsequently, however, the hypothesis of the gravitational ether was not supported. In the book "Field Theory" (Landau and Lifshitz, 2006), the possibility of propagation of electromagnetic waves in empty space was still explored. Yet, since empty space has no size (see above), there is nowhere for electromagnetic waves to propagate.

Since then, the problem of the metric properties of space was forgotten for a long time. Now, to denote the medium of the interstellar space, the definition "space vacuum" is most commonly used. However, translated from Latin, vacuum is a void, which does not exist in nature (see above). Therefore, the use of such a concept does not solve the problem of the existence of the space metric properties.

The proposed MoBC theory gives a new look at the nature of space and its properties, and revises the explanation of the origin of our universe.

3. WORLD SUBSTANCE

The MoBC assumes, that there is a special kind of matter present in nature, hereinafter – World Substance (ether). It's the only matter that has the property of extension. With this property the World Substance determines the metric of the Universe, that is, it creates a metric space which contains ordinary matter (elementary particles, the bodies they constitute and radiation) and various fields. As it was proved above, the emptiness cannot exist in nature. Thus, the World Substance, as well as the space created by it cannot have boundaries or interruptions. The world substance exists always and everywhere.

It is known that space is absolutely transparent for the movement of material objects of ordinary matter, including radiation. This is possible if objects of ordinary matter, including photons, do not interact with the World Substance.

The absolute transparency of space can be explained using an analogous effect of absolute transparency in the medium of ordinary matter. A good example is superconductivity and superfluidity. Both effects are the result of the existence of an energy gap (D. R. Tilley and J. Tilley, 1974). It was demonstrated, that superconductors at ultralow temperatures exhibit an energy gap, that appears between the energy of the Cooper pairs electrons condensation and the energy of phonon excitations that determine the electrical resistance of the superconductor (Bardeen, Cooper, and Schrieffer, 1957).

Similarly, according to calculations, there is an energy gap in superfluid helium between the energy of motion of liquid HeII and the spectral minimum of roton excitations of the vessel walls responsible for friction (Landau, 1946).

Using these effects as an analogy, one can assume that the absolutely transparent movement of the ordinary matter in the outer space (including photons) can be explained by the presence of a significant energy barrier preventing the interaction of elements of ordinary matter with the World Substance. This can also explain the negative results of the experiment to detect the influence of ether on the measured speed of light (Michelson and Morley, 1887). Due to the fact that the World Substance does not interact with ordinary matter, the ordinary matter cannot also serve as a frame of reference.

Dark matter and dark energy are the two objects of the universe that are being intensively studied today. Their nature is not clear. Dark Matter manifests itself as a gravitational influence on the rotation of spiral galaxies and as the lensing effect (see Begeman, Broelis, and Sanders, 1991; de Blok and McGaugh, 1997; Einasto, 2009). The Dark Energy is believed to be responsible for antigravity, which accelerates the expansion of our universe (Chernin, 2008). Dark Matter and dark energy objects do not interact with photons and are therefore invisible.

Based on the parsimony of nature, one can argue that two objects sharing similar property may turn out to be the same object. The shared property in this case is the invisibility of dark matter, dark energy, as well as the World Substance. Hence, one can assume that dark matter and dark energy are components of the World Substance. Hence several inferences are possible.

Inference 1. The World Substance has a gravitational component uniformly distributed over the entire space, which includes dark matter and dark energy.

Inference 2. The World Substance does not interact with elements of ordinary matter due to the presence of the large energy barrier preventing such interaction.

Inference 3. The Big Bang disturbed part of the gravitational component (dark matter). The disturbance spread at a very high speed over a vast space (by cosmological standards). As a result, areas with positive gravity concentrations - Dark Matter, and, accordingly, areas with predominantly negative gravity - Dark Energy - were formed.

Inference 4. The Dark Matter concentration areas experienced galactic scale Dark Matter density fluctuations. When density reached critical level in such an area, a phase transition of dark matter was possible, where it transformed into ordinary matter as high-temperature plasmoids.

4. THE BIRTH OF THE UNIVERSE

The MoBC theory takes into account the modern knowledge about the composition and structure of our universe and offers the following picture of its origin. Initially (before the Big Bang), the World substance always existed everywhere and always, creating an infinite, flat, isotropic space without borders and interruptions. In this space, Dark Matter (DM) and Dark Energy were uniformly distributed with a total mass / energy density equal to the critical ρ_c. The Big Bang disturbed DM. DM disturbances have spread over a vast by cosmological standards space. (The Giant Fluctuation could well have been the Big Bang.) The large-scale DM concentration areas (positive gravity) reaching one megaparsec (1pc = 3.3 light-years) were forming as a result of the Big Bang. Together they organized a web-like structure (filaments). Areas of space with predominantly negative gravity (Dark Energy) were also forming accordingly.

When DM condensed into these large-scale concentrations, DM vortices (including cylindrical vortices) also formed. Small-scale (the size of a galaxy) condensations (fluctuations) of the DM density were ubiquitously in excitement. In these DM density fluctuations or DM vortices, the density of DM could reach a critical level, and as a result, a phase transition of DM into ordinary matter could happen, where DM transformed into particles of ordinary matter. The phase transition manifested as the formation of high-temperature plasma build-ups of various shapes - plasmoids, consisting of ordinary matter elementary particles and radiation. The symmetric amplitude DM fluctuations formed Plasmoids in the form of plasma balls. The vortices formed plasmoids in the form of rotational elipsoids or highly compressed plasma disks. Thus, during the Big Bang, large-scale DM concentration areas contained flaring up inclusions of plasmoids – the embryos of future galaxies.

After the plasmoids cooled down to a temperature of 3000 K, the stage of recombination began (Gorbunov and Rubakov, 2008). Atoms of neutral hydrogen, helium, and lithium were forming from electrons and protons. This resulted in the plasmoids turning into gaseous build-ups of neutral atoms, and the radiation (photons) freely scattered throughout the Universe in the form of CMB. Later, stars started to form in the gas clouds. As a result, large and small elliptical, spiral and other galaxies were formed depending on the type of plasmoids.

Thus, according to the MoBC concept, galaxies consisting of baryonic matter were formed from the phase transitioning DM (the formation of plasmoids) in the places of critical concentration of its density and subsequent cooling of plasmoids.

The presence of DM halos in all the studied galaxies (Begeman, Broelis, and Sanders 1991; de Blok and McGaugh 1997; Einasto 2009) confirms the connection between galaxies and DM concentrations.

The density distributions of the dark halo in spiral galaxies are described with the following distribution:

$$\rho = \rho_0 \left[1 + \left(\frac{r}{r_c}\right)^2\right]^{-1}, \tag{5}$$

where ρ_0 is the maximum density of the DM halo, r_c is the half-decay radius of the halo density. The r_c parameter varies for different galaxies within the range of 2-100 kpc (for the studied galaxies with radii of 8-50 kpc – Begeman, Broelis and Sanders 1991; de Blok and McGaugh; 1997). The presence of a DM halo with distribution (5) explains the flat rotation curves of the majority of the studied spiral galaxies.

According to the MoBC theory, the galaxies' rotation speed is initially derived from the different rotation speeds of DM vortices. The dark mater spiral vortices' rotation momentum was transferred to the baryonic matter plasmoids during the transition phase. After the recombination stage, the rotation was preserved in neutral hydrogen gas clouds. At present, rotation is most pronounced in spiral galaxies.

Stationary (non-rotating) globular star clusters were created from stationary plasma balls, that formed from DM amplitude fluctuations without rotation.

Billions of years later, spiral galaxies are still in the places where they formed – in the vortices of DM. This means that the observed recession of galaxies (see, for example, Gorbunov and Rubakov 2008) is actually the recession of DM concentration areas with galaxies fixed in them.

5. CONCLUSION

We devised the scenario of the birth of the Universe based on the new concept of the cosmological theory – MoBC, including the explanation of the birth of baryonic matter, the galaxies formation and the reasons for their rotation. It is possible to clarify some of the problematic issues of cosmology that are constantly discussed in scientific publications.

1. The question of cosmological concordance - the uniformity of the mass density/energy density of the Universe components: Dark Energy, Dark Matter and ordinary (baryonic) matter. In the proposed MoBC, the phenomenon of cosmological coincidences is explained by the formation of these components in one act of the Big Bang from one object - the gravitational component of the World substance. Ordinary (baryonic) matter was formed in the form of plasmoids as a result of a phase transition in the small-scale critical concentrations of Dark Matter. Moreover, the excitation of Dark Matter during the Big Bang was of such power that as much as 15% of Dark Matter transitioned into plasmoids, consisting of ordinary matter and radiation.
2. The rotation of galaxies is inherited from the rotation of various vortices of Dark Matter (including cylindrical vortices) that occurred in the course of the Big Bang with the flow of Dark Matter into large-scale concentrations. The rotation momentum of the DM vortices was transmitted during the phase transition to the plasmoids, from which, after their cooling, rotating spiral galaxies were formed.
3. Search for the world constants (h, c, G, etc.) providing the possibility of the existence of our Universe and ultimately life, becomes irrelevant. The world substance with its gravitational components (Dark Matter and Dark Energy), as shown above, has always existed, therefore, all the constants of the Universe, most likely, are laid down in the parameters of the World substance. In addition to our Universe, other Universes can form in other places of the World Substance, and they will have the same world constants, therefore life can also exist in them.

The specifics of the Dark Matter fluctuations appearance, the various Dark Matter vortices generation, as well as the formation of galaxies and their structure are considered in subsequent articles of this essay collection.

Problems for possible further research not covered in the article collection:

- the nature of the phase transition in Dark Matter, which results in the formation of baryonic matter in the form of plasmoids;

- the processes inside plasmoids, leading to the ejection of hot plasma and the formation of spiral galaxies arms; reasons for the initial fluctuations of the CMB.

The most important of all questions: what exactly is the Universal Substance in which everything is located; which we do not see and therefore do not study.

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2. FORMATION OF GALAXIES FROM CRITICAL FLUCTUATIONS OF DARK MATTER. CYLINDRICAL VORTICES OF DARK MATTER

The unexpectedly high concentration of massive galaxies in the early Universe (at redshift z> 4-10) does not agree with the predictions of the standard cosmological theory. Difficulties with the ΛCDM theory also arise when explaining the motion features of the vast polar structures of satellite galaxies found in spiral galaxies in near-space (Milky Way, Andromeda, and Centauri A). These failures of the standard cosmological theory have stimulated us to propose a modification to the foundations of cosmology, which is as of follows. Before the Big Bang, there was space and there was uniformly distributed Dark Matter in it. Ordinary (baryonic) matter was absent. The Big Bang produced large-scale concentrations of Dark Matter and various Dark Matter vortices, including thin cylindrical vortices. At the same time, local fluctuations of the Dark Matter density of a galactic scale appeared everywhere, including at the center of cylindrical vortices. In the Dark Matter fluctuations with a critical density, phase transitions occurred with the formation of high-temperature plasma build-ups (plasmoids) consisting of primary particles of ordinary matter and radiation. After the plasmoids cooled down, galaxies of various types and sizes were formed. Spiral galaxies formed in the middle of the cylindrical vortices. For example, our Galaxy with a diameter of about 30 kpc (1 pc = 3.26 light years) and a rotation speed of about 200 km/s was formed in the middle of a thin cylindrical DM vortex with a height of about 600 kpc and a diameter of about 4 kpc.

Keywords: Dark Matter, Big Bang, Dark Matter vortices, Dark Matter fluctuations, phase transition, plasmoids, galaxies.

1. INTRODUCTION

Recent studies of deep space at redshift z> 4 have shown an unexpectedly high concentration of massive protogalaxies (Wang et al.2019, Steinhardt et al., 2016), which questioned the proposed mechanism of formation and evolution of galaxies within the framework of the standard cosmological theory based on cold Dark Matter and constant Λ (Lambda Cold Dark Matter - ΛCDM). It turned out that the number of massive galaxies z > 4 - 10 is several orders of magnitude higher than predicted by calculations (Mueller et al. 2018).

According to the ΛCDM theory, galaxies are formed through the flow of baryonic matter (mainly hydrogen gas) into potential wells prepared by concentrations of Dark Matter (Dark Matter - DM) (Okabe et al. 2013, Berezinsky et al. 2014, Longair 2008, Piontek, Steinmetz 2011 , Harvey et al. 2017).

Fig. 1 shows the curves (solid) of the theoretical concentrations of massive galaxies distribution at redshifts 4 <z <10 and the observation results (points) at the same redshifts (Steinhardt et al. 2016). Data in fig. 1 implies that in the early Universe, at z = 10, the concentration of massive galaxies with a mass of $6 \cdot 10^{12}$ $M_{\odot}$ equals $1 \cdot 10^{-6}$ $h^3 Mpc^{-3}$ (lower left point), which is more than 4 orders of magnitude higher than the calculated data in the

ΛCDM theory (left projected curve, for z = 10). The observed concentration of galaxies and the nature of their distribution changes little in the range 4 <z <10.

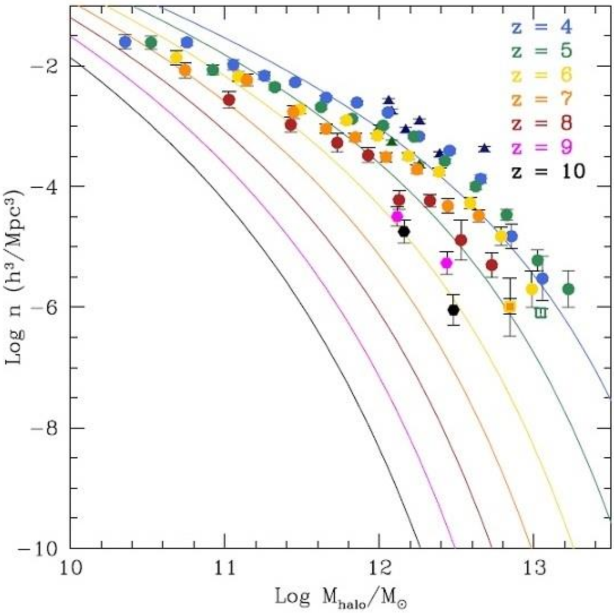

Fig. 1. Theoretical density of the galaxies halos number as a function of mass and redshift for the most massive halos at 4 <z <10 (shown with solid lines, left curve at redshift z = 10) compared with the observational density number of the corresponding halo masses at similar redshifts (shown as dots) (for details, see Steinhardt et al. 2016).

The large concentration of early galaxies indicates a shorter time of their formation than is required for the gas to flow into local concentrations of Dark Matter (proposed in the ΛCDM theory). Therefore, it is necessary to propose a faster mechanism for the origin of galaxies.

On the other hand, three spiral galaxies have been observed in near space, and all of them have extensive polar structures of satellite galaxies, the motion of which also does not agree with the predictions of the ΛCDM theory (Müller et al. 2018).

Fig. 2 shows the observation results of the satellite galaxies structure distribution in our Milky Way (MW) galaxy, consisting of dwarf spheroidal galaxies, globular star clusters and gas (Pawlowski et al. 2012, Fouquet et al. 2012, Pawlowski et al. 2013).

The nearest galaxy to the Milky Way, Andromeda (M31), located at a distance of 2.5 million light-years has at least 13 satellite galaxies coaxially rotating around the main galaxy (Pawlowski et al. 2013, Mc Connachie, Irwin 2006, Koch, Grebel 2006). Finally, the fifth brightest galaxy Centaurus A (Cen A), located at a distance of 10-16 million light-years from

MW, shows 14 out of 16 satellites with measured kinematic data rotate coherently with Cen A around the single axis (Müller et al., 2018).

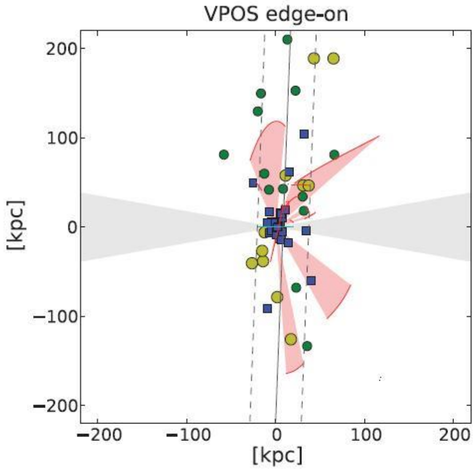

Fig. 2. The extensive polar structure of the MW galaxy (side view). The Y-axis points to the north pole of the MW galaxy. Satellite galaxies are shown as large points, globular star clusters are shown as squares. Separate thin curves connect the gas flow anchor points. The MW galaxy is shown in the center as a short horizontal line. (For details, see Pawlowski et al. 2012).

The existence of non-spherical satellite galaxies structures of the nearest spiral galaxies (MW, M31 and Cen A), coaxially rotating around the main galaxy, challenges the modern understanding of the ordinary matter structures formation at the subgalactic level. In most cases, a close to isotropic distribution and random kinematics for galactic satellite systems are expected in the ΛCDM model. The galaxy formation simulations based on the ΛCDM model suggest that the probability of similar to the MW's polar structures of satellite galaxies is less than 0.05% (Ibata et al. 2013, Kroupa, et al. 2005). The formation of such structures in all three galaxies in near space is even more improbable. This again signals the necessity to reevaluate the mechanism of formation and evolution of galaxies proposed by the ΛCDM model.

In order to explain the observations of experimental astronomy, which do not agree with the predictions of the ΛCDM theory, this paper uses the Modified Basics of Cosmology (MoBC) theory (see the previous article) explaining, among other things, the origin and formation of the galaxies structure.

2. THE FORMATION OF GALAXIES FROM CRITICAL FLUCTUATIONS OF DARK MATTER

The MoBC theory interpretation (see previous article 1) stipulates that there was a uniformly distributed Dark Matter in infinite space before the Big Bang. Ordinary (baryonic) matter was absent. During the Big Bang, large-scale concentrations of Dark Matter (mpc scale) began to form. During the flow of DM into large-scale concentrations, turbulences were present together with the formation of DM vortices (including thin cylindrical DM vortices). Simultaneously, local fluctuations of the galactic-scale DM density were happening everywhere, including inside the cylindrical DM vortices. Within the critical Dark Matter fluctuations phase transitions occurred with the formation of high-temperature plasma build-ups (plasmoids) consisting of primary particles of ordinary matter and radiation. Later gaseous structures and star clusters (galaxies) were formed inside the cooled plasmoids.

Rotating critical DM density fluctuations appeared in the center of the cylindrical vortices. The ensuing phase transitions resulted in the formation of rotating plasmoids. After they cooled down, spiral galaxies were formed.

Thus, the proposed work explains the emergence of ordinary matter from DM fluctuations through the stage of the high-temperature plasma build-ups (plasmoids) formation, which consisted of the primary particles of ordinary matter and radiation.

Before the Big Bang, there was a uniform mass/energy distribution in infinite space with a critical density of ρ_c= 0.85 · 10^{-29} g/cm^{-3}(Dolgov 2014). Ordinary (baryonic) matter was absent. Therefore, the proportion of Dark Matter was Ω_M = (Ω_{MD} + Ω_b) = 0.317 (where Ω_{MD} and Ω_b are the modern proportions of dark and ordinary matter (Dolgov 2014)). Consequently, the initial density of Dark Matter is ρ_{m0} = $\Omega_M \cdot \rho_c$, which is 4 · 10^{-8} Mpc^{-3}.

It is known from thermodynamic theory, that in any large system local fluctuations of its parameters are possible. There is the so-called square root law (Prigozhin, 1978), according to which the average relative fluctuation of a certain parameter in a large system is inversely proportional to the square root of its average value. Consequently, in the case of Dark Matter, the average value of density fluctuations $<\delta\rho>$ is proportional to the square root of the DM density $<\delta\rho> \sim \rho^{1/2}$. In the course the Big Bang, the DM density increases (compared to the initial values) in the formed large-scale concentrations and, as such, $<\delta\rho>$ increases too. The presence of large-scale DM concentrations was revealed by studying the relative motion of galaxies in clusters, as well as by the lensing effect (Okabe et al. 2013). The DM density can be tens of times higher than that of baryonic matter in galaxy clusters and may reach 1.5 10^{15} hM Mpc^{-2} (Okabe et al. 2013), (the Hubble parameter h equals 0.73) (Dolgov 2014). If we take into account the DM concentration sphericity (Okabe et al. 2013) (approximately 500 kpc), then the density in the center of a concentration is 3.4 10^{-3} Mpc^{-3}. Thus, the average DM density in large-scale galaxy clusters is increased by almost 10^5 times compared to the initial density. The average fluctuations $<\delta\rho>$ are increased by $10^{2.5}$ times accordingly. Since $\delta\rho$ most likely had a Gaussian distribution (Landau, Lifshitz 1995), it possible, that in some fluctuations the density of $\rho + \delta\rho$ could reach the critical value, and as a result, in such DM fluctuations a Dark Matter-ordinary matter phase transition in the form of a high-temperature plasmoid could occur.

The existence of relict radiation supports the hot plasma stage hypothesis of the baryonic matter emergence from critical DM fluctuations (Weinberg 2008, Gorbunov, Rubakov 2008). After the plasmoids cooled down to 3000 K (the stage of recombination), the relict radiation was released, and the stage of the star systems formation (galaxies) – began (Gorbunov, Rubakov 2008).

3. CYLINDRICAL VORTICES OF DARK MATTER

In the course of Big Bang, the formation of large-scale DM concentrations can be represented as a flow of a compressible material medium (Dark Matter), in which turbulence could arise. The turbulence resulted in various DM vortices formation (including cylindrical ones). At the center of the vortices, conditions could arise for the appearance of local critical DM fluctuations with rotation. During the phase transition, rotating plasmoids emerged from them, and after their cooling, spiral galaxies were formed.

Although Dark Matter vortices are invisible, satellite galaxies and the central spiral galaxy can be thought of as test bodies that rotate in the gravitational field of the DM vortex and mark the boundaries of its action. In the case of the MW galaxy with its companion galaxies (see Fig. 2), one can imagine some dimensions of the DM vortex and its structure.

The data from fig. 2 implies that the satellite galaxies, globular star clusters, and the MW galaxy in the center represent a cylinder of limited height. Satellite galaxies and globular star clusters in Fig. 2 are shown as large dots and squares, respectively. Separate thin curves show the flows of gas. Our Galaxy (MW) in Fig. 2 is shown in the center as a short horizontal line.

The shape of the vortex associated with the MW galaxy can also be represented by the 3D animation attached to the work (Pawlowski et al. 2012). In the next work of Pawlowski et al., the systems of satellite galaxies are designated in the form of “pillars” (red or blue crosses) and the galaxies MW and M31 themselves (in the form of rings) (Pawlowski et al. 2013, Fig. 6). The “pillars” characterize the corresponding cylindrical rotating satellite systems of the MW and Cen A galaxies.

From the data of the same work, it follows that satellite galaxies are distributed relative to the central galaxies MW or M31 up to a distance of 300 kpc (Pawlowski et al. 2013, Fig. 1). This distance can be considered the length of the semiaxis of the cylindrical systems of satellite galaxies related to MW or M31. Hence, we can conclude that the DM vortex, which formed the MW galaxy and its satellites (Fig. 2) is a cylindrical vortex with a long axis of about 600 kpc and a diameter of the effective satellite galaxies attraction of 60-100 kpc.

The formation of various vortices was previously studied in detail in hydro- and aerodynamics in the flow of liquid or gas (Friedman 1966, Leibovich 1983, Grabowski, Berger 1976, Lotov 2002). The theory of cylindrical, aerodynamic Q-vortices was developed in the work of Leibovich (Leibovich, 1983). The theoretical profile of the radial change in the velocity v (r) of the matter rotation in the Q-vortex was calculated:

$$v(r) = qr^{-1}[1 - \exp(-r^2)], \tag{1}$$

where q is a certain positive constant. Experimental data on the radial distribution of the Q-vortex velocity were also presented (Leibovich 1983, Fig. 6). In the middle of the Q-vortex, a “vortex core” is observed, where the vortex rotation speed quasilinearly increases with distance from the center (as in a solid body, where rotation with a constant angular velocity of body particles can be observed). Beyond the “core” the rotation rate practically does not change with an increase in the distance from the center of the Q-vortex.

It is also known (Lotov, 2002) about the interaction and decay of aerodynamic vortices. When cylindrical vortices approach each other with the opposite direction of rotation, they begin to move in parallel perpendicular to the axis of rotation. If cylindrical vortices rotate in one direction, then they merge into a single large vortex.

The decay of an aerodynamic vortex can occur due to instability (fluctuation) along the axis of the vortex (S-decay) or due to the dissipation of the angular momentum into the space surrounding the vortex (B-decay) through the formation of a bubble **(**Leibovich 1983, Grabowski, Berger 1976).

The accumulated data of the Q-vortices theory can be used as an analogy in the analysis of the cylindrical DM vortices structure. The nature of the radial distribution of stars and gas rotation curves in spiral galaxies, which are in the gravitational field of cylindrical DM vortices, is determined by the distribution of the Dark Matter density in the vortex.

The curves of the stars and gas rotation velocity’s radial distribution in a number of spiral galaxies were presented in the several works (Rubin et al. 1978, 1980, Einasto 2012). With distance from the center of galaxies, the rotation speed of stars and hydrogen gas is increasing at first, and then remains practically constant $v_{max}(r)$ = const throughout the examined radii. It is believed that the flat nature of the stars and gas rotation velocity’s radial distribution in spiral galaxies is due to the presence of Dark Matter (Einasto 2012**,** Begeman et al. 1991, De Blok, McGaugh 1997).

4. ROTATION SPEED DISTRIBUTION OF GALAXIES

In this paper, based on the rotation data of a number of typical spiral galaxies, the density of DM distribution is calculated under the assumption of cylindrical vortices. The experimental profiles of the change in the rotation speed of a number of spiral galaxies are shown in Fig. 3 (curves with dots). The data was retrieved from published works (Rubin et al. 1980, Begeman et al. 1991).

The data on Fig. 3 implies that the profiles of radial changes in the rotation velocity of spiral galaxies are similar to the experimental profiles of the rotation velocity of an aerodynamic Q-vortex (Leibovich 1983, Fig. 6). Starting from the center, the rotation speed of all galaxies grows quasilinearly up to a certain maximum value of vmax. Let this region be the “core of the galactic vortex”, where the galaxy rotates like a solid disk with the constant angular velocity. After reaching the maximum rotation velocity at the edge of the core, the rotation velocity of matter in the galaxy does not change when the radius increases further.

Calculations have shown that the velocity profiles *v(r)* of most spiral galaxies can be described by an empirical formula similar to equation (1) only without the cofactor of r^{-1}:

$$v(r) = v_{\max}\left\{1 - exp\left[-\left(\frac{r}{R_G}\right)\right]\right\}, \qquad (2)$$

where R_G is the decay parameter of *v(r)* in the core of the galactic vortex.

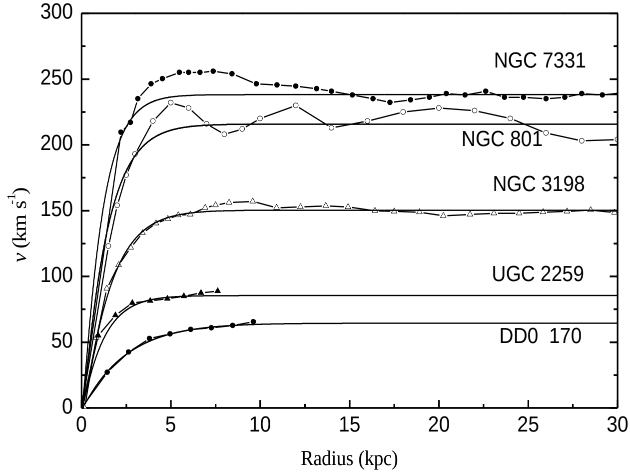

Fig. 3. Curves of the rotation velocity distribution of a number of galaxies (curves with dots - experimental data, solid curves - calculation taking into account the mass distribution in the central section of the cylindrical DM vortices, where the spiral galaxies are located). The experimental data (points) were reconstructed from the published works (Rubin et al. 1980, Begeman et al. 1991).

Spiral galaxies rotate in the joint gravitational field of the galaxy and the corresponding cylindrical DM vortex. The rotation velocity squared of stars or gas (test bodies) in a certain gravitational field according to Newton's law, can be determined through the equation

$$v^2(r) = g(r)r, \qquad (3)$$

where *g(r)* is the acceleration determined by the general distribution of gravitating masses. Next, one can apply the Gauss-Ostrogradsky theorem for the local vector fields. When applied to the strength of the gravitational field (for the Dark Matter concentration area), the Gauss-Ostrogradsky theorem will have the following notation: (Ilyin et al. 1987)

$$\iiint\limits_V div\boldsymbol{g} = \iint\limits_S \boldsymbol{g}_n \qquad (4)$$

where $\boldsymbol{g}$ is the vector of the gravitational field strength in the DM concentration. Equation (4) describes the equality of the *div* $\boldsymbol{g}$ integral over certain selected volume with the projection flow of the vector $\mathbf{g}_n$ onto the allocated volume surface normal.

Let us choose a certain cylindrical cut of radius r with height h in the cylindrical DM vortex. As a first approximation, we consider the vector gn in the middle part of the DM cylinder to vary little with in relation to height h. Due to the cylindrical symmetry of the system, the vector g is perpendicular to the lateral surface of the cylinder and is directed towards the inside of the surface. According to the work of Ostrogradsky (Ostrogradsky 1959)

$$div\, \boldsymbol{g} = -4\pi G\rho(r), \tag{5}$$

where G is the gravitational constant, $\rho(r)$ is the DM mass density in the vortex with a radius r. From (4) and (5) we obtain the following equations:

$$-4\pi G \int_0^r \rho(r')2\pi r' dr' h = -g(r)2\pi r h,$$

$$2G \int_0^r \rho(r')2\pi r' dr' = g(r)r. \tag{6}$$

Substituting (6) into (3), we obtain the equation for calculating the radial distribution of the galaxies' rotation velocity in the gravitational field of the cylindrical DM vortex:

$$v^2(r) = 2G \int_0^r \rho(r')2\pi r' dr'. \tag{7}$$

Calculations have shown that it is possible to align the profiles of the galaxies' rotation velocity $v(r)$ with the experimental profiles by representing the radial DM density distribution $\rho(r)$ in a cylindrical vortex through the equation

$$\rho(r) = \rho_0 \left\{1 - exp\left[-\left(\frac{r}{R_a}\right)\right]\right\} exp\left[-\left(\frac{r}{R_d}\right)\right], \tag{8}$$

where the R_a determines the decay of the DM density towards the center of the vortex, R_d is the exponential decay of the density at the cylindrical DM vortex periphery. We selected R_a and R_d in the equation (8) using the equation (7) so that they resulted in the $v(r)$ profiles, that are close to the experimental ones. The first cofactor determines the dip in the DM density as a result of centrifugal forces. The second cofactor is determined by turbulence forces effect in the rotating DM flow.

Fig. 3 shows the calculated rotation velocity profiles $v(r)$ of a number of galaxies (solid lines) using the (7) equation and the experimental data for the same galaxies (curves with dots) retrieved from the published works (Rubin et al. 1980, Begeman et al. 1991). These calculations are for the NGC 7331, NGC 801, NGC 3198, NGC 2259 spiral galaxies and the DDO 170 dwarf galaxy.

In fig. 3, one can see wave distortions on the experimental curves $v(r)$ of a number of massive galaxies.

5. MASS DISTRIBUTION IN CYLINDRICAL VORTICES OF DARK MATTER

Fig. 4a shows the calculated distributions *ρ(r)* of cylindrical DM vortices using the (8) equation, where the corresponding spiral galaxies are located. The data in Fig. 4a implies that the density of Dark Matter *ρ(r)* in the vortex grows rapidly with an increase in the rotation speed of a galaxy**,** going from 0.017 M/pc^3 (the DDO 170 galaxy, v_{max} = 64.5 km/s) to 0.973 M/pc^3 (the NGC 7331 galaxy, v_{max} = 237 km/s). It is clear from equation (7) that the mass of cylindrical DM vortices is proportional to the corresponding v_{max}^2. Therefore, the normalization of *ρ(r)* to the corresponding v_{max}^2 allows us to examine the profile of the mass distribution in the DM vortices in more detail (see Fig. 4b). In this case, the area under the normalized curves $\rho(r) / v_{max}^2$ is the same for all vortices.

The R_d and R_a affect the curve of the rotation velocity decay in the core of the galactic vortex in Fig. 3. It turned out that with decreasing v_{max}, the R_d increases. Accordingly, the exponential decay of *ρ(r)* at the periphery of the cylindrical DM vortex slows down. The vortex with the massive galaxy NGC 7331 has the R_d = 0.8 kpc, while the dwarf galaxy DDO 170 has the R_d = 1.8 kpc.

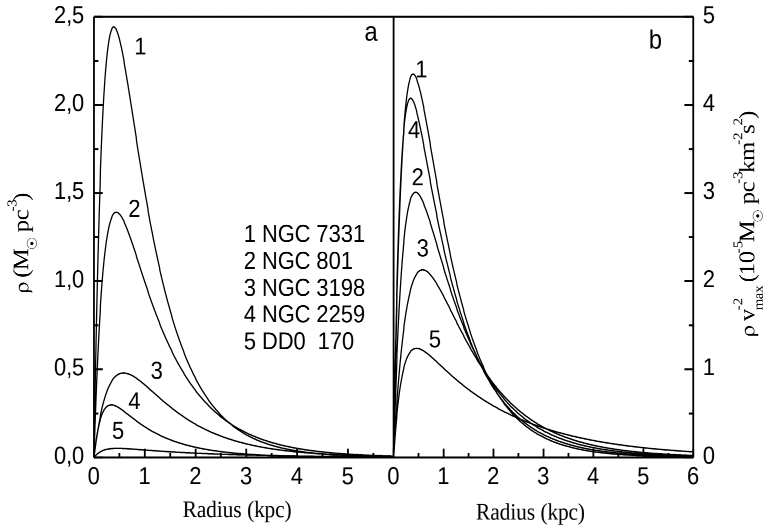

Fig. 4. The distributions of mass density in the central cut of cylindrical DM vortices with the corresponding galaxy in the center: a) the distributions of *ρ(r)* in the middle part of the DM vortex in a 1 kpc thick disk (in the region of the galaxy location) and b) the distributions of $\rho_n(r)$, normalized to the corresponding v_{max}^2.

It is possible to determine the characteristic diameter of the cylindrical DM vortices, which includes 75% of the vortex mass. From the data obtained, it follows that as the rotation speed of the galaxy increases, the cylindrical DM vortex becomes more massive and its characteristic diameter shrinks from 9.7 kpc (the DDO 170 galaxy) to 3.9 kpc (the NGC 7331 galaxy). As already mentioned, the height of the cylindrical DM vortices with the galaxies MW and M31 is about 600 kpc (Pawlowski et al. 2013). In small galaxies, such as DDO 170, the vortex height can be much less.

In spiral galaxies, one can observe the effects with DM vortices similar to those of aerodynamic Q-vortices**.** The approaching cylindrical DM vortices with galaxies NGC 2207 and IC 2163 have different directions of rotation and therefore, like aerodynamic vortices (Lotov 2002), most likely move parallel to the plane of visibility in the direction perpendicular to the straight line connecting their centers.

In case of S-decay (instability on the axis of the cylindrical DM vortex), some dwarf satellite galaxies can collapse, forming gas flows inside the DM vortex (see Fig. 2). A complete loss of satellite galaxies in a spiral galaxy is also possible.

In case of B-decay of a single vortex, the spiral galaxy or plasmoid in its center can get an expansion disturbance, resulting in the formation of irregular galaxies (type I). An example is the NGC 55 galaxy. In the case of a merger of two vortices, two galaxies can receive mutual disturbance. As a result, irregular, mixed type II galaxies are formed. An example is the Antennae galaxies consisting of the NGC 4038 and the NGC 4039 galaxies. Their nuclei are only 20 kpc apart.

In some cases, as a result of the joint S- and B-decay, the entire contents of the vortex (the central plasmoid and its satellites) may unfold in space, for example, in the form of the Magellanic Stream – clouds of neutral hydrogen). According to Putman et al. 2003, the mass of the Magellanic Stream is about $2 \cdot 10^8 \, M_\odot$. Thus, according to the Tully-Fischer relation (McGaugh and Schombert 2015), the dwarf plasmoid, which completely unfolded as a result of the decay of the DM vortex, had a rotation speed of about 50 km/s.

Outside the vortices, in the laminar flow region of DM, spheroidal fluctuations of the DM density were appearing. From such fluctuations during the phase transition, plasmoids in the form of spheres or ellipsoids with a low rotation speed were formed. In this case, after the recombination stage (Gorbunov, V.A.) elliptical galaxies of various types began to form in them: from E0 (spherical) to E7 (oblate spheroids), where the number denotes different degrees of compression of the spherical (ellipsoidal) structure of the galaxy (as an example – the M87 (E0) galaxy in Virgo constellation or the NGC 3923 (E4) galaxy in Hydra constellation).

6. CONCLUSION

Thus, the MoBC proposes the following scenario for the formation of our Universe.

Originally there is Euclidean (Planck collaboration, 2016) and therefore infinite space. A gravitational substance is uniformly distributed throughout space, which is a “mixture” of Dark Matter and Dark Energy. Ordinary (baryonic) matter was absent. At some point in time, at some place, there was a Big Bang. It is possible that it was a Giant Fluctuation. The Big Bang stirred up the gravitational substance at a great distance. As a result, large-scale (the order of Mpc) areas of positive gravity (Dark Matter) concentrations began to form resulting a kind of grid structure - filaments. In the process of the flow of Dark Matter into large-scale concentrations, conditions for turbulence appeared. As a result, various vortices of Dark Matter have appeared, including thin cylindrical DM vortices with a diameter of about 4-10 kpc and a height of up to 600 kpc.

In the course of Dark Matter concentration, its density increased up to 105 times (up to 3.4 10^{-3} Mpc^{-3}). Such a significant increase in the density of Dark Matter literally led to its "boiling", that is, to the ubiquitous appearance of local fluctuations of the DM density. In cylindrical DM vortices, where the DM density could reach 0.97 Mpc^{-3}, local DM disturbances have appeared. In the critical DM disturbances, high-temperature plasmoids, consisting of primary particles of ordinary matter and radiation, began to flare up. After the plasmoids cooled down to 3000 K, the CMB and neutrinos left the plasmoids. As a result, gaseous protogalaxies were created, in which star systems began to form – galaxies of various types.

Taking into account modern data on the distribution of matter in the Universe (Dolgov 2014), it turns out that as a result of the "boiling" stage, as much as 16% of DM transitioned into ordinary matter in the form of plasmoids. In the region of the laminar flow of Dark Matter, spheroidal critical fluctuations of DM appeared, which eventually led to the formation of spheroidal plasmoids and then the formation of galaxies of the E0 - E7 type.

At the center of the cylindrical DM vortices, rotating regions of the critical density DM were formed, which led to the appearance of high-temperature rotating plasmoids. After they cooled down to 3000 K, spiral galaxies began to form. Small critical clumps DM were formed along the axis of the vortex, which turned into dwarf plasmoids, from which dwarf satellite galaxies were created. The disintegration or collision of cylindrical DM vortices led to various distortions of spiral galaxies or to the complete unfolding of plasmoids in space and, accordingly, to the formation of gas flows between galaxies.

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3. FORMATION OF THE SBbc SPIRAL GALAXIES STRUCTURE

According to modified cosmology (see Articles 1 and 2), large-scale concentrations and vortices of Dark Matter, including thin cylindrical vortices, were formed during the Big Bang. Simultaneously, local fluctuations of the galactic-scale DM density appeared everywhere. In critical DM perturbations, phase transitions occurred with the formation of high-temperature plasma build-ups (plasmoids), consisting of primary particles of ordinary matter and radiation. After the plasmoids cooled down, galaxies of various types and sizes were formed. Rotating DM fluctuations appeared in the center of the cylindrical vortices, from which rotating high-temperature plasmoids were formed during the phase transition. As a result of plasma ejection in the plane of rotation of the plasmoid, a structure of spiral galaxies was formed: bulge, links, and spiral arms (SBbc type galaxies). The continuous stream of plasma ejection lasted hundreds of millions of years and could start several times creating a complex picture of the structure of galactic spirals.

Key words: Big Bang, Dark Matter concentrations, Dark Matter vortices, local Dark Matter fluctuations, phase transition, plasmoids, plasma ejection, structure of spiral galaxies.

1. INTRODUCTION

A number of observations of experimental astronomy are inconsistent with the predictions of the standard cosmological theory based on cold Dark Matter and Dark Energy (Lambda Cold Dark Matter - ΛCDM) (Wang et al. 2019, Steinhardt et al. 2016, Müller et al. 2018). In this regard, it was proposed to modify the foundations of cosmology (the Modified Basics of Cosmology – MoBC) (see previous articles), explaining, among other things, the origin and formation of galaxies. According to the MoBC, prior to the Big Bang, uniformly distributed Dark Matter (DM) existed in infinite space. Ordinary (baryonic) matter was absent. As a result of the Big Bang, large-scale concentrations of DM began to form. In this case, vortices of DM also appeared, including thin cylindrical vortices. Simultaneously everywhere local fluctuations of the galactic-scale DM density appeared. Phase transitions with the formation of high-temperature plasma build-ups (plasmoids), consisting of primary particles of ordinary matter and radiation, occurred in critical DM fluctuations. Rotating critical DM fluctuations appeared inside the cylindrical vortices. As a result of phase transitions, high-temperature rotating plasmoids were formed from them. Spiral galaxies formed after cooling of rotating plasmoids.

In this paper, based on the MoBC concepts, it is proposed to consider the process of formation of the stellar structure of a spiral galaxy of the SBbc type, which occurs as a result of plasma ejection from the rotating central plasmoid and its subsequent cooling and formation of stars.

2. FORMATION OF THE SCUTUM–CENTAURUS, PERSEUS AND SAGITTARIUS STAR ARMS IN THE MILKY WAY GALAXY

Calculations show (see the previous article) that the radial distribution of the rotation speed *v(r)* of spiral galaxies is due to the joint gravitational action of the galaxy's substance and the DM vortex. A typical distribution curve *v(r)* consists of two sections (article 2, fig. 3). Starting from the center of the galaxy, *v(r)* increases at first, and then reaches a plateau up to vmax, remaining unchanged throughout all the measured radii. The section of the *v(r)* dependence, where the rotation velocity grows quasilinearly up to vmax, is the region of the "galactic vortex core", where the galaxy matter (gas and stars) rotates like a solid disk with the same angular velocity. This paper shows that the dependences *v(r)* in the region of the galactic vortex core substantially depends on the radial distribution of the matter density *ρ(r)* in a cylindrical cut along the center of the DM vortex, where the spiral galaxy is located.

As in the previous article, we represent the distribution *ρ(r)* by the empirical relation

$$\rho(r) = \rho_0 \left\{1 - exp\left[-\left(\frac{r}{R_a}\right)^{\alpha}\right]\right\} exp\left[-\left(\frac{r}{R_d}\right)^{\beta}\right], \tag{1}$$

where the parameter R_a determines the decay of the DM density towards the center of the vortex, R_d is the parameter of the exponential decay of the density at the periphery of the cylindrical DM vortex. The introduced additional exponents α and β significantly affect the shape of the distribution of *ρ(r)* and, therefore, the distribution of matter in the core of the spiral galaxy.

The speed of rotation *v(r)* depends on the strength of the gravitational field *g(r)* (acceleration) and is calculated from the relation (2):

$$v^2(r) = g(r)r, \tag{2}$$

In the case of a cylindrical vortex (shown in the previous article), the acceleration depends on *ρ(r)* of the radial DM mass distribution in the vortex:

$$g(r) = \frac{2G}{r}\int_0^r \rho(r')2\pi r' dr', \tag{3}$$

where *G* is the gravitational constant.

Using the equation (3), we obtain the dependences of *v(r)* on *ρ(r)*:

$$v(r) = 2G\int_0^r \rho(r')2\pi r' dr', \tag{4}$$

At the plateau of the dependence of *v(r)* on *r*, the outgoing plasma in the arms of spiral galaxies being at different distances from the center of the galaxy will lag behind the rotation in the galactic nucleus during the rotation of the galaxy according to the following relation

$$\Delta\varphi(r) = [v(r_n)r_n^{-1} - v(r)r^{-1}]t, \tag{5}$$

where r_n is a certain radius in the core of the galactic vortex, and *t* is the time period from the beginning of the plasma ejection from the plasmoid. After the plasma has cooled, stars and gas concentrations form in the arms of the galaxy. Therefore, the astronomical data on the structure of the arms of a real galaxy reflect the ejection of hot plasma from the central plasmoid.

Calculating a certain dependence of the position $r_{arm}(t)$ of the plasma substance in the galaxy arm on the beginning of the plasma ejection, the calculation parameters are tuned to match the data of the digitized stellar spirals of the galaxy.

Fig. 1 shows the final results of the Milky Way structure calculation. The calculations of the $r_{arm}(t)$ dependence for the Scutum–Centaurus, Perseus, and Sagittarius arms are well approximated by such equations as (6)

$$r_{arm}(t) = at^2 + bt^3, \tag{6}$$

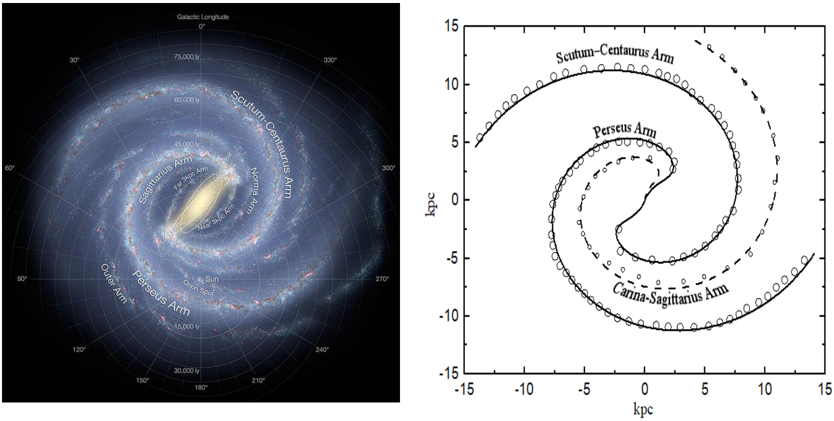

Fig. 1. The calculations for the Scutum–Centaurus, Perseus, and Sagittarius arms in the Milky Way galaxy. The points are the digitized curves of the sleeves from the picture on the left. In the calculations (on the right), a galactic nucleus with a diameter of about 8 kpc with practical, straight bars is seen in the center. The curves of the Scutum–Centaurus and Perseus arms were calculated with the same parameters using the equation (1).

3. RATE OF PLASMA DISCHARGE FROM PLASMOID AT THE MOMENT OF STAR ARMS FORMATION

Fig. 2 shows the calculated conditions for the ejection of plasma from the central plasmoid during the formation of the structure of the Milky Way galaxy.

Curve 1 on Fig. 2a (dots) represents the experimental data (Sofue 2009) measuring the rotation speed $v(r)$ in the Milky Way galaxy (MW). Curve 2 shows the calculated dependence $v(r)$ at the time of the First double plasma ejection and the formation of the Scutum–Centaurus and Perseus arms. Curve 4 shows the corresponding distribution of $\rho(r)$ in the middle of the cylinder DM vortex at the moment of formation of these arms. The first plasma ejection lasted 163.2 million years.

The beginning of the formation of the Sagittarius arm during the Second plasma ejection occurred after the beginning of the First plasma ejection approximately 60 million years later (determined by comparing the ends of the arms of the Scutum–Centaurus and Sagittarius). The second plasma ejection lasted 135.4 million years. Curve 3 shows the calculated dependence *v(r)* at the moment of the Second plasma ejection and the formation of the Sagittarius arm. In this case, a different distribution of *ρ(r)* was obtained in the middle of the cylindrical DM vortex (curve 5) at the moment of the Sagittarius arm formation.

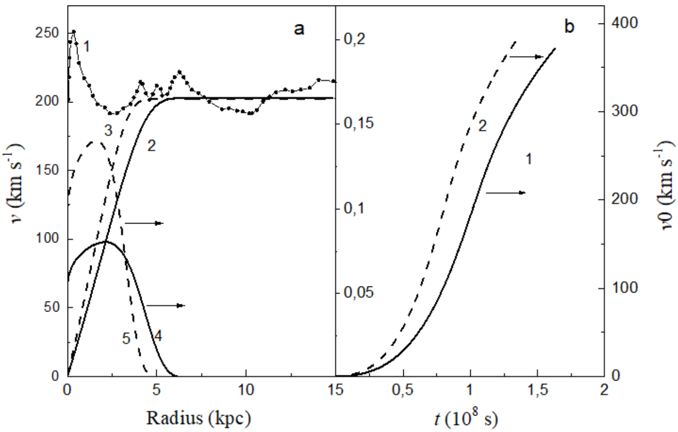

Fig. 2. The conditions in the Milky Way galaxy during the formation of the Scutum–Centaurus, Perseus and Sagittarius arms. a) The measured distribution (curve 1) (Sofue 2009) of the rotation velocity of the MW galaxy and the calculated distribution of the rotation velocity (curve 2) and the DM density in the vortex (curve 4) during the process of the First plasma ejection. Curves 3 and 5 show the corresponding data for the time of the Second plasma ejection. b) Velocity curves for the First plasma ejection (curve 1) and the Second plasma ejection (curve 2). The beginning of the plasma ejection is counted from the end of the curve.

After the plasma escapes, the kinetic energy of the plasma particles is completely absorbed by the work of the DM vortex gravity forces on the way to the final steady-state position of matter in the arm of the galaxy:

$$mV_0^2(r_{arm}) = 2m\int_0^r g(r_{arm})\,dr, \tag{7}$$

where V_0 and m is the escape velocity and the assumed mass of particles (protons) in the ejected plasma.

Using the $r_{arm}(t)$ dependences for arms obtained from relation (6), the dependence of the initial flight velocity V_0 (r_{arm}) for the corresponding point with r_{arm} on the arm curve was calculated.

Fig. 2b shows the $V_0(t)$ curves for the Scutum–Centaurus and Perseus arms (curve 1) and the Sagittarius arm (curve 2). The last point on the graph Fig. 2b (at maximum r_{arm} (t)) is the beginning of the plasma ejection, and respectively the initial velocity (kinetic energy) of particles in the ejected plasma. Then, the velocity (energy) of the emission of particles in the plasma gradually drops to zero (in the galactic nucleus). Time on the graph in Fig. 2b from the beginning of the plasma ejection is in a reverse order.

Although with the evolution of the DM mass distribution shape the conditions in the cylinder vortex changed from the First plasma ejection to the Second ejection, the velocity (energy) of the plasma ejection remained unchanged - about 383 km/s. If the main particles in the plasma were protons (neutrons), then the energy of the onset of the plasma ejection was 76.6 keV, which corresponds to an effective temperature in the plasma of $5.9 \cdot 10^6$ K.

4. CONCLUSION

Thus, the formation of the structure of spiral galaxies is caused by the ejection of high-temperature plasma from the central plasmoid, and their specific configuration is determined by the radial distribution of mass over the cross section at the center of the Dark Matter vortex.

Appendix 1 shows galaxies resulting from different types of hot plasma ejections from the central plasmoid. At the initial high energy of the plasma jet, its subsequent additional decay into two (or several) plasma arms is possible, and then multiple branching of the galaxy arm (galaxy M83) is observed in the galaxy. A simultaneous multiple ejection of plasma in all directions (in the plane of rotation) and the decay of the initial part of the plasma flow into separate jets (galaxy NGC 3982) is possible. There are galaxies that have two rings of star clusters near the galactic nucleus (NGC 7742). This is due to two plasma ejections with a small difference in kinetic energy. In some galaxies (for example, NGC 1300 and M83), the arms are close to the galactic nucleus, which can be explained by the smaller diameter of the galactic nucleus at the beginning of the plasma ejection and its increase towards the end of the plasma ejection, or the change in the energy of the plasma jet during the flight.

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4. SPIRAL GALAXIES PARADOX

According to astronomical observations, the angular velocity of the spiral galaxies rotation decreases with distance from the center. Since galaxies have existed for billions of years, under such conditions of rotation we should observe a blurred disk-like structure of galaxies. However, in practice, a huge number of galaxies are observed with a "frozen in time" spiral structure. Thus, there is a paradox between the modern data on the rotation of spiral galaxies and the long retention time of their spiral structure. Retention of the spiral structure of the galaxy is possible only if the angular velocity of rotation of all parts of the galaxy is the same. That is, the speed of rotation of parts of a spiral galaxy should be strictly proportional to the distance to its center. Within the framework of the previously proposed Modified cosmology, the process of formation of the galaxies spiral structure and their stabilization in time are described. Spiral arms in galaxies are the result of the ejection of several hot plasma jets from a central high-temperature rotating plasmoid formed from a critical disturbance of Dark Matter in the middle of a Dark Matter cylindrical vortex. The stabilization of the plasma arms of the galaxy in the corresponding orbit ("freezing") occurs as a result of the acceleration of the plasma jet sections to the speed of the Dark Matter vortex rotation driven by dynamic friction from the rotating gravitational field of Dark Matter.

Keywords: cylindrical vortices of Dark Matter, plasmoids, formation of arms of spiral galaxies, dynamic friction in a gravitational field, stabilization of the spiral structure of galaxies

1. INTRODUCTION

Spiral galaxies have a special curves shape for the radial distribution of the stars and gas rotation velocities, which differs from the rotation of planetary systems (Rubin, 1978, 1980; Einasto, 2012; Begeman, 1991). With distance from the center of the spiral galaxy, the rotation speed of stars and hydrogen gas initially increases to a certain maximum value, then remains practically constant throughout the examined radii (Fig. 1). This leads to the fact that the angular velocity of rotation of galaxies parts decreases with distance from the center of the galaxy.

On the other hand, spiral galaxies have formed spiral structures of stars and hydrogen gas that persist for billions of years. Our Galaxy, the Milky Way (MW), has two main arms: Scutum–Centaurus and Perseus (Benjamin, 2008) (Fig. 2). These two arms recede from the center of the galaxy up to a radius of 14.5 kpc (1 pc = 3.26 light years). The radial distribution curve of the MW galaxy rotation speed reaches a constant speed of about 200 km/s (Sofue 2009).

Regardless of the mechanism for the formation of spiral arms during long-term rotation (1 billion years or more), the spiral structure of the MW galaxy should be completely blurred due to the retardation of the arms' distant sections rotation speed.

Other spiral galaxies, similar to those in Fig. 1 with the radial distribution of the rotation speed (Rubin, 1978, 1980), should have lost their spiral structure. Therefore, we should not observe spiral galaxies, but solid thin discs of hydrogen gas. However, many galaxies observed at different times from the moment of the Big Bang have, like the MW galaxy, a clear spiral structure. It seems as if the spiral structure of galaxies is "frozen in time". Consequently, there is a certain paradox between the modern data on the spiral galaxies speed distribution of radial rotation and the long-term existence of spiral galaxies.

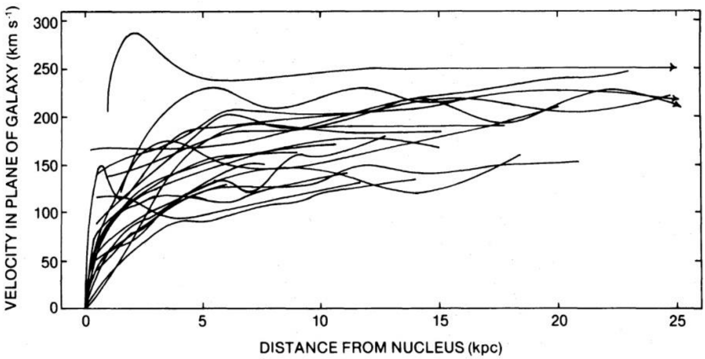

Fig. 1. Superposition of 21 rotation curves of Sc type galaxies. The general shape of the rotation curves for small galaxies (lower curves) is similar to the initial part of the rotation curve for large galaxies (Rubin 1978).

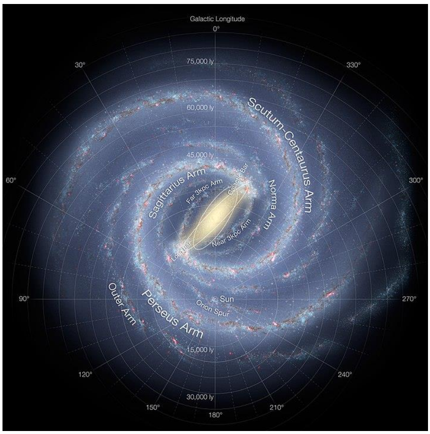

Fig. 2. Artistic representation of the Milky Way galaxy. The main sleeves are Scutum-Centaurus and Perseus (Benjami, 2008).

In this paper, the abovementioned paradox is considered and the mechanism of the spiral galaxies arms formation and of their spiral structure "freezing in time" is proposed.

2. SPIRAL GALAXIES PARADOX

The results of recent studies of deep space at redshifts of $4 < z < 10$ showed an unexpectedly high concentration of massive galaxies (Wang et al. 2019, Steinhardt et al. 2016), which indicates an earlier formation of galaxies than calculated in the framework of the standard cosmological theory of Dark Energy and Cold Dark Matter (Lambda Cold Dark Matter - LCDM). According to the LCDM theory, galaxies are formed through the flow of baryonic matter (mainly hydrogen gas) into potential wells prepared by condensations of Dark Matter (see, for example, Harvey et al. 2017; Surdin, 2019). Therefore, it is necessary to propose a faster mechanism for the formation of galaxies after the Big Bang.

On the other hand, in near space, the structure of three spiral galaxies has been studied in detail, and all of them have extensive polar structures of satellite galaxies, the motion of which is coherent with the rotation of the central galaxy. These observations also disagree with the predictions of the LCDM theory (Pawlowski et al. 2012, 2013; Müller et al. 2018).

In this regard, the Modified Basics of Cosmology (MoBC) (article 1) has been proposed to explain these observations of experimental astronomy.

The MoBC concept is as follows. Before the Big Bang, there was space and there was uniformly distributed Dark Matter (DM) in it. Ordinary (baryonic) matter was absent. During the Big Bang, the wave of disturbance of Dark Matter "instantly" spread in an enormous volume. Simultaneously, large-scale concentrations of DM began to form (filaments). Turbulences also appeared, leading to the formation of DM vortices (including cylindrical ones). In addition, a strong concentration of DM has led to the emergence of many local fluctuations of the DM density on a galactic scale. Phase transitions with the formation of high-temperature plasma build-ups (plasmoids), consisting of primary particles of ordinary matter and radiation, occurred in critical DM fluctuations (article II). After the plasmoids cooled down, galaxies of various types and sizes were formed. Rotating DM fluctuations appeared in the middle of the cylindrical DM vortices. As a result of the phase transition, these DM fluctuations turned into high-temperature rotating plasmoids. Then, the arms of a spiral galaxy were formed from the rotating plasmoid as a result of the ejection of hot plasma (article III), and after their cooling, stars were formed.

MW galaxy was formed in the middle of a cylindrical DM vortex with a height of approximately 600 kpc and an effective diameter of approximately 8 kpc. Calculations for the Scutum-Centaurus, Perseus and Sagittarius arms formation were performed.

Fig. 3a shows the results of the MW galaxy Scutum-Centaurus and Perseus arms structure calculations (smooth curves - article 3) and the digitized data of these arms from Fig. 2. The calculation was performed based on the MW galaxy rotation velocity distribution data (Sofue, 2009). The Scutum-Centaurus and Perseus arms were formed as a result of the simultaneous ejection of two high-temperature plasma jets from opposite sides of the link in the plane of rotation of the galaxy. In the process of plasma ejection, the kinetic energy of the ejected plasma jet gradually decreased. Therefore, the radius of the stationary orbit, to which the corresponding plasma build-up flew, gradually decreased. The lag angle of the arm section relative the rotation of the central part of the plasmoid also decreased. The total time of the MW galaxy main arms formation is approximately 160 million years (article III).

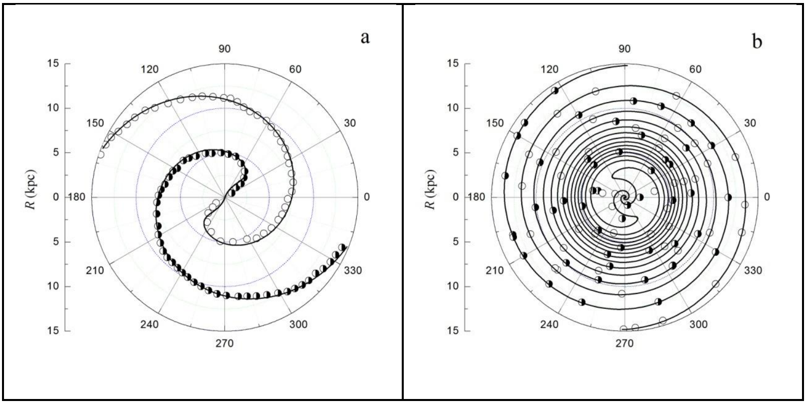

Fig. 3. Calculations of the Scutum-Centaurus and Perseus arms structure in the Milky Way galaxy. a) The points are the digitized curves of the arms from Fig. 2. Solid curves show the calculation for the spiral formation time of 163 million years (article III). b) Calculations with the rotation time of the galaxy extended by 1.5 billion years.

Fig. 3a: a good alignment between the calculated structure of the arms (smooth curves) and the digitization of data from Fig. 2 (shown as dots). However, the extension of the MW galaxy rotation time by 1.5 billion years in calculations creates a strongly twisted structure, as shown in Fig. 3b. That is, the spiral structure of the MW galaxy disappears.

Other spiral galaxies, the radial distribution of the rotational speed of which is similar to the data in Fig. 1, during their existence should have also lost their spiral structure. Thus, we are dealing with a paradox between modern data on the rotation of spiral galaxies and the long-term existence of the spiral structure of galaxies.

3. “TIME-FREEZE” OF THE GALAXIES SPIRAL STRUCTURE

The MW galaxy was formed about 13.5 billion years ago, somewhat earlier than its oldest star HD 140283 (Frebel 2007). This is almost at the very beginning after the Big Bang. If the rotation of the MW galaxy at the very beginning was the same as it is now, it would lead to the formation of a thin disk of gas with insufficient concentration of gas to form stars. That is, there would be no Sun, planet Earth and us - people who would observe spiral galaxies.

On the other hand, many photographs of spiral galaxies, regardless of their distance (age), show a clear spiral structure. In this case, a certain pattern is observed. The outermost parts of the stellar arms in spiral galaxies lag behind the rotation of the central part of the galaxy by almost the same fraction of a revolution. At the end of the article collection (Appendix 2) a number of galaxies at different distances from the Sun are presented. The arms of the galaxy NGC 2997 are 1 revolution behind (the distance to the galaxy is 39 million light years) (Hess, 2009). The earliest galaxy BX 442 (10.7 billion light years) (Law et al. 2012), the ISOHDFS 27 galaxy (6 billion light years) (ECO0041, 2000), and Comet Galaxy

(3.2 billion light years)) (Cortese, 2006) – all have their arms at 0.5 revolutions behind. Our galaxy MW has a lag of 0.83 revolutions (Fig. 2).

The retention of the spiral structure of galaxies at different times of the Universe existence without significant swirling indicates a kind of "freezing in time" of the galaxies spiral structure. According to the MoBC, spiral galaxies rotate in the gravitational field of the corresponding cylindrical DM vortex (Article II). The "frozen" state of the galaxies spiral structure is possible only if the galaxies rotate together with the DM vortex inside its core. The core of a vortex is a vortex region rotating like a rigid body, that is, with the same angular velocity as we move away from its center (Leibovich, 1983).

In this case, the speed of rotation of the galactic regions is proportional to the distance *r* from the center to this region with a proportionality coefficient equal to ω_0 - the angular speed of DM rotation in the core of the cylindrical DM vortex:

$$v(r) = \omega_0 r. \tag{1}$$

In accordance with Newton's law, the speed of rotation of stars or gas (as test bodies) in a certain gravitational field squared, can be determined through the equation:

$$v^2(r) = g(r)r, \tag{2}$$

where *g(r)* is the acceleration determined by the distribution of gravitating masses (of the galaxy and cylindrical DM vortex). Taking into account equations (1) and (2)

$$g(r) = \omega_0^2 r. \tag{3}$$

In accordance with the Ostrogradsky-Gauss Theorem (Ilyin, 1987; Ostrogradsky, 1959), at the center of the cylindrical DM vortex the following equality holds (article 2)

$$g(r)r = 2G \int_0^r \rho(r')2\pi r' dr', \tag{4}$$

where *G* is the gravitational constant, *ρ(r)* is the radial density distribution of Dark Matter in the middle of the cylindrical vortex where the galaxy is located.
Taking into account (3), we obtain

$$\omega_0^2 r^2 = 2G \int_0^r \rho(r')2\pi r' dr'. \tag{5}$$

If we take the derivative relative to *r*, then

$$\omega_0^2 2r dr = 2G\rho(r)2\pi r dr. \tag{6}$$

From (6) it follows that the distribution *ρ(r)* in the core of the cylindrical DM vortex is a constant:

$$\rho(r) = \rho_0 = \frac{\omega_0^2}{2\pi G}. \tag{7}$$

The distribution of the gravitational field potential of such a DM vortex:

$$\Psi(r) = \int_0^r g(r')dr' = \frac{\omega_0^2 r^2}{2}. \quad (8)$$

In fig. 4, the scheme of the formation and "freezing" of spirals is considered based on the example of the MW galaxy located in the core of a cylindrical DM vortex rotating with a certain angular velocity ω_0.

As a result of certain processes in the central rotating plasmoid 3', a link was formed, from which the plasma was ejected with a mass of Δm. The ejection Δm occurs in the direction of straight line 4 in Fig. 4. In fact, the movement to a stationary orbit of radius *R* occurs along the curve 4', since the force of gravitational dynamic friction *F* acts on the plasma build-up Δm (Lancaster et al., 2020; Orlov and Raikov, 2014) (denoted by an arrow in Fig. 5) from the side of the Dark Matter wind in the DM vortex:

$$F(r) = 4\pi\rho(r)\left(\frac{G\Delta m}{v'(r)}\right)^2, \quad (9)$$

where $v'(r)$ is the speed of the build-up Δm relative to the Dark Matter flow in the core of the DM vortex. In turn, $v'(r)$ is equal to the difference between the velocity of the DM vortex $v(r) = \omega_0 r$ at the radius *r* and the velocity v_1 of the build-up Δm, acquired under the action of the force $F(r)$ on the path 4'

$$v'(r) = \omega_0 r - v_1(r). \quad (10)$$

At the kinetic energy of the ejected plasma build-up $\Delta m V_0^2/2$, it reaches a certain equilibrium radius *R* in the potential field (8) of the DM vortex in the period of time *t1*:

$$\frac{\Delta m \cdot V_0^2}{2} = \Delta m \frac{\omega_0^2 \cdot R^2}{2}, \quad (11)$$

where V_0 is the exit velocity of the plasma build-up.

In the time period of t_1, the central plasmoid with the link rotated through the angle $\omega_0 t_1$, and the piece of the plasma build-up Δm acquires the kinetic energy of rotation around the center of the galaxy and shifts by the angle $\Delta\varphi$ relative to straight line 4 in Fig. 4. Then

$$\frac{1}{2} m v_1^2 = \int_0^{\Delta\varphi} F(r') r' d\varphi, \quad (12)$$

where $F(r)r$ is the force momentum acting on the plasma build-up when moving along the curve 4 'to an equilibrium trajectory with radius *R*. At the end point, with radius $r = R$, the build-up velocity $v_1(r)$ becomes equal to $\omega_0 R$ rotation speed of the DM vortex. The velocity $v'(r)$ of the plasma build-up Δm relative to the rotating Dark Matter in the vortex becomes equal to zero - the plasma build-up is "frozen" in an orbit with a radius of *R*.

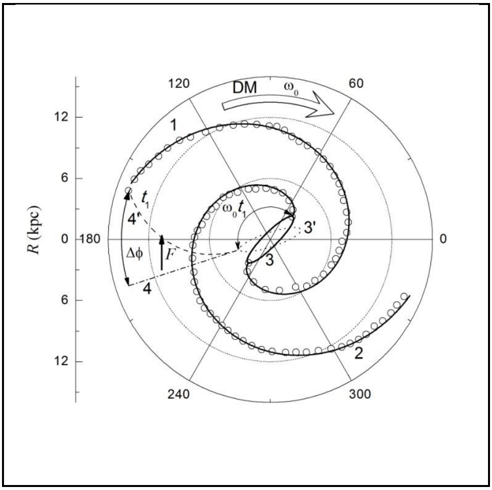

Fig. 4. The scheme of the formation and "freezing" of the Scutum-Centaurus and Perseus spirals of the MW galaxy in the core of a cylindrical vortex of Dark Matter rotating with an angular velocity ω0.

The remaining build-ups of the plasma jet, ejected immediately after the first build-up, with a lower kinetic energy (article 3), undergo the same "freezing" in the corresponding orbits with a smaller radius and with a smaller lag shift $\Delta\varphi$. During the period of time *t1*, the final spiral structure of the Scutum-Centaurus and Perseus arms is formed (curves 1 and 2 in Fig. 4), and the central plasmoid with a link (curve 3 ', Fig. 4) turns during the same time by the angle $\omega_0 t_1$ (curve 3, fig. 4).

As an example, calculations for Fig. 4 were performed for the case of the angular velocity of Dark Matter rotation in a vortex ω_0 = 8.356 10^{-16} s^{-1}, equal to the angular velocity of the Sun rotation around the center of our Galaxy. Then, according to (7), the density of Dark Matter in the core of the vortex is ρ_0 = 0.025 Mpc^{-3}, and the initial velocity of the plasma jet during the formation of the Scutum-Centaurus and Perseus arms was 368.7 km / s. If there were protons in the plasma jet, the effective temperature of their escape would be 4.95 10^6 K.

4. CONCLUSION

Thus, according to the MoBC concept, the formation of galaxies occurs almost immediately after the Big Bang, after the cooling of plasmoids, which were formed from critical fluctuations of Dark Matter formed during the Big Bang. The complex spiral structure of galaxies is created by the ejection of several jets of plasma from a high-temperature plasmoid formed in the middle of a cylindrical vortex of Dark Matter.

At present, there is no clear understanding of the nature of Dark Matter; therefore, the question of the nature of the critical DM fluctuation phase transition into a high-temperature plasmoid remains open. Also unknown are the processes inside a rotating, high-temperature plasmoid, which lead to repeated ejection of a plasma jets.

Stabilization of the structure of spirals of galaxies ("freezing") is associated with the acceleration of the outgoing parts of the plasma jet to the speed of rotation of Dark Matter in the vortex under the action of dynamic friction from the side wind of Dark Matter. The radius at which a part of the plasma in the spiral arm is stabilized is determined by the kinetic energy of plasma jet and the potential energy of Dark Matter in the DM vortex core at this radius. For specific calculations, in addition to data on the topology of spiral arms, it is necessary to determine the true radial distribution of the galaxy's rotation velocity. To stabilize ("freeze") the spiral structure of the galaxy, this speed must increase in strict proportion to the distance from the center of the galaxy. That is, the rotation angular velocity of all spiral galaxies' sections should be strictly the same and equal to the rotation angular velocity Dark Matter in the core of the cylindrical DM vortex.

Most of the modern data on the radial distribution of the spiral galaxies' rotation speed obtained on the basis of the Doppler effect show a decrease in the angular rotation speed of spiral galaxies when the distance from the center of the galaxy increases. This fact constitutes a paradox with the long-term existence of the spiral structure of galaxies. Perhaps, when determining the rotation speed of spiral galaxies by the Doppler effect method, it is necessary to take into account the dynamic friction on photons (Zwicky, 1929) from the Dark Matter vortex.

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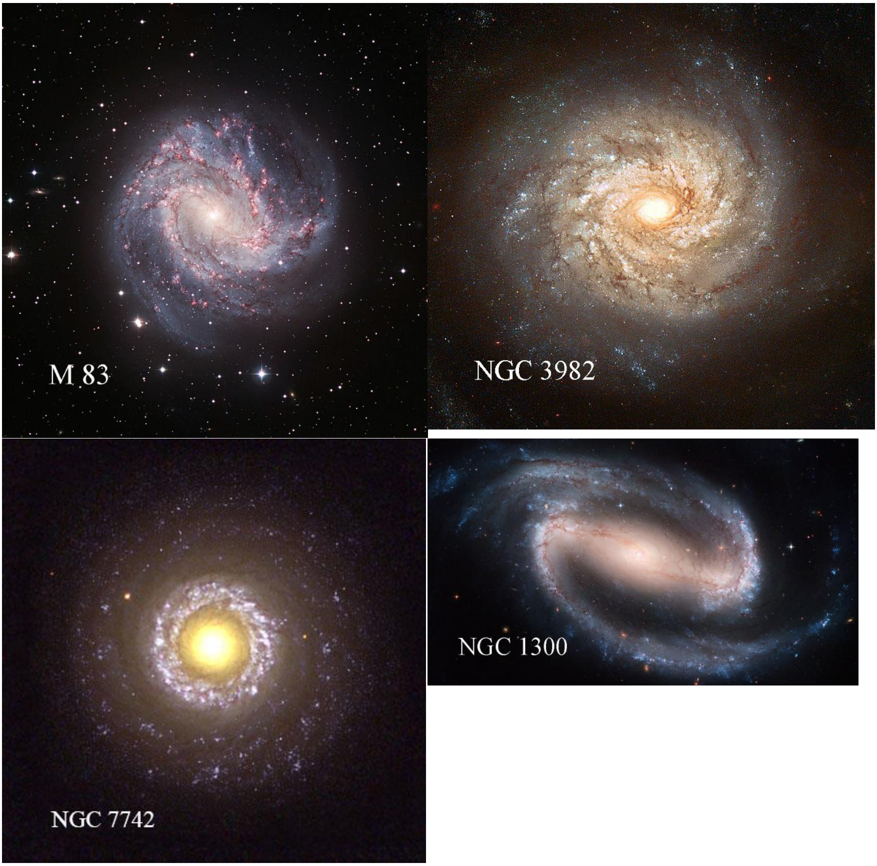
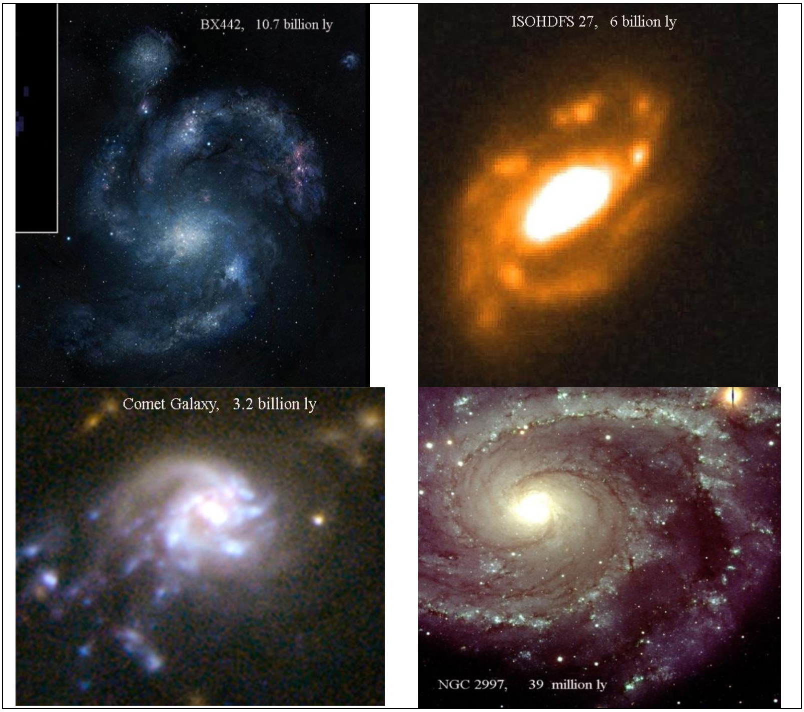
Appendix 1



Galaxies resulting from various types of hot plasma ejections from the central plasmoid. Galaxy M83 – At the initial high energy of the plasma jet, its subsequent additional decay into two (or several) plasma arms is possible, and then multiple branching of the galaxy arm is observed in the galaxy. Galaxy NGC 3982 – Simultaneous multiple ejection of plasma in all directions (in the plane of rotation) and the decay of the initial part of the plasma flow into separate jets. Galaxy NGC 7742 – Two rings of star clusters are observed near the galactic core. This is a result of two plasma ejections with a small difference in kinetic energy. Galaxies NGC 1300 and M83B – arms are close to the galactic nucleus, which can be explained by the smaller diameter of the galactic nucleus at the beginning of the plasma ejection and its increase towards the end of the plasma ejection, or the change in the plasma jet energy during the ejection.

Appendix 2



The view of spiral galaxies at different distances from us (respectively, back in time): the earliest galaxy BX 442 (10.7 billion light years) (Law et al. 2012), the ISOHDFS 27 galaxy (6 billion light years) (ECO0041, 2000), the Comet Galaxy (3.2 billion light years) (Cortese, 2006), and the NGC 2997 galaxy (39 million light years) (Hess, 2009).

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THE MODIFIED BASICS OF COSMOLOGY. GALAXIES

Article collection

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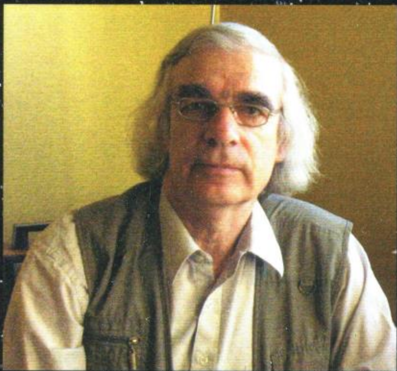

"... there is a paradox between the modern data on the rotation of spiral galaxies and the long retention time of their spiral structure..."

V. Leiman