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Consequences of electrical non-neutrality of the Universe

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Abstract

Photonics, optics, and optical metrology, as well as quantum optics and photonic engineering and space metrology provide us with empirical knowledge about the Universe. The theoretical description of the Universe is implemented within the framework of the so-called Standard Model. It allows for the explanation of phenomena as exotic to us as processes at distance scales thousands of times smaller than the size of a proton, but also processes in the interiors of stars, or the evolution of matter in the Universe for fractions of seconds after its creation. Thanks to optical research techniques, physical theories are being verified regarding the components of the Universe and its physical nature, as well as the processes occurring in it. It is optical observations that have provided science (and first of all – physics) with facts, the explanation of which requires answers to questions about the nature of Dark Matter and Dark Energy. This work is devoted to the search for answers about the nature of Dark Matter and Dark Energy.

1. Introduction

It is commonly believed currently the Universe came into being in a great act of creation of energy from the so-called Great Singularity, in a process called the Big Bang (BB). The history of the Universe is commonly described in the form of Eras within the Standard Model [1–3].

The Standard Model began with the Planck Era, which lasted until about 10^{-43} s. The next were: the Grand Unification Era (it is assumed that it lasted: 10^{-44}–10^{-30} s), then the Quark-Gluon Plasma Era (10^{-30}–10^{-6} s) next the Hadron Era (10^{-6}–10^{0} s), and then the Lepton Era (10^{-6}–10^{1} s), the Radiation Era (until about 400 thousand years), and the Stellar Era (it lasts until now). The first stars formed after about 100 million years and the first galaxies after about 200 million years. Each Era had a different course. The important fact is that in the Universe, a huge predominance of matter over antimatter can be observed.

The Standard Model claims that the process of baryogenesis with the breaking of the C, P, and CP symmetries of weak interactions is to some extent responsible for this inequality of matter and antimatter [1, 4–6]. In the author's opinion, this inequality results from the breaking of the spin symmetry or rather chiral symmetry at the beginning of the Grand Unification Era and its consequences for subsequent Era in the development of the Universe. Starting from the Radiation Era, physicists are basically in agreement about the further course of evolution of our Universe.

The author's own considerations and analyses show that the Universe is characterized by a large electrical positive charge [7]. The value of the mass endowed with an unbalanced positive charge is comparable to the electrically balanced mass of the Universe, and perhaps even greater. The unbalanced positive charge is created primarily by protons (nuclei of hydrogen atoms). It may also be created by atomic nuclei of deuterium and tritium, perhaps by helium nuclei – but this is already to a much smaller extent.

The earliest, in conditions of unimaginably high temperature and extremely high-energy density, quarks and gluons were created, from which later baryons (including protons and neutrons) and mesons were created. Leptons, among which electrons dominated, were created later – in the Lepton Era, still at very high temperature (but lower than in the previous Era), under conditions of lower matter-energy density.

Electrons were created already in the process of creating matter and antimatter with opposite (negative and positive) electric charges. This process was accompanied

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by the annihilation of leptons and antileptons, and then their subsequent generations and annihilations. A huge number of protons and neutrons were created because the earliest quarks and gluons were created in conditions that were very extreme on the one hand, but at the same time very favourable for this process. The conditions for the creation of leptons were not so favourable. Electrons existing in the Universe were created mainly from the decay of neutrons. The basic process of neutron decay took place in another Era – at the beginning of the Radiation Era, when the process of creating matter in the Universe had practically ended. It is inconceivable to the author that protons and electrons were created in the same quantity and that every proton in the Universe found an electron to create an electrically neutral hydrogen or helium atom. The same applies to other nuclei of light elements. The Universe is not electrically neutral – it is electrically charged with a large, very large positive electric charge.

The principle of conservation of charge in the Universe today tells us that the total charge present in the Universe is constant. But in the author's opinion, it is not zero. The opinion expressed in the scientific literature on cosmology that "*no phenomena have been observed that could indicate that the total charge of the Universe is different from zero*" in the author's opinion is unjustified and incorrect.

The electrical neutrality of the Universe is an unjustified scientific belief, not a physical fact.

2. Dark Matter

The richness of interactions in the Universe is unimaginable. It is estimated that the number of galaxies in the Universe is at the level of 10^{12} and the average number of stars in a galaxy is estimated to be over 10^{11}. (The Universe is estimated to contain an unimaginable amount of 10^{23}–10^{24} stars). About 10% of the estimated number of 10^{12} galaxies are so-called active galaxies. The characteristic feature of active galaxies is that they emit a huge amount of electromagnetic radiation – much greater than "normal" galaxies. This phenomenon is not related to the energy of stars located in these galaxies, but to radiation from a wide range of the electromagnetic spectrum emitted from the core of galaxies. This radiation is dependent on the activity of the active supermassive black hole located in the core of the galaxy. The literature on cosmology and astrophysics contains a lot of information and results on active galaxies. These are often new results from the last few or a dozen years [8–13].

Observations of galaxies rotation conducted for dozens of decades indicate that stars distant from the galaxy cores move much faster than would result from analyses using Newtonian dynamics methods (Fig. 1).

Both observational studies of galaxy rotation and theoretical analyses of most galaxies indicate that the accelerated rotation of stars distant from the galaxy centre, i.e., the so-called flat characteristics of galaxy rotation, is due to an additional, unobserved mass located inside the galaxy, as well as in its external environment in the form of a galactic halo. There is significantly more (even several times) of missing galactic mass than luminous mass. The missing mass is referred to as Dark Matter. Much of the physical nature of Dark Matter is a scientific mystery [14–16]. The classical division of Dark Matter divides it into so-called baryonic matter and non-baryonic matter. Baryonic matter is made up of classical elementary particles known to science – it is made up of: nebulae, neutron stars, brown dwarfs, Jupiter-type planets, black holes, including small black holes… This matter is located in galactic disks, although it is not excluded that it is located in the galactic halo. It is estimated that there is relatively a little baryonic Dark Matter: about 10–30% of the galaxy mass. The rest of the mass of the halo is a non-baryonic Dark Matter, also called "exotic". Science still does not know what exotic (yet undetected) particles constitute the main mass of the galactic halo. Despite great experimental efforts undertaken for several decades, none of the theoretical concepts of Exotic Dark Matter particles has been experimentally confirmed. To date, science does not know what constitutes a significant part of the "missing" mass of the Universe. The literature – both scientific and popular science – on the subject of Dark Matter is abundant [15–17].

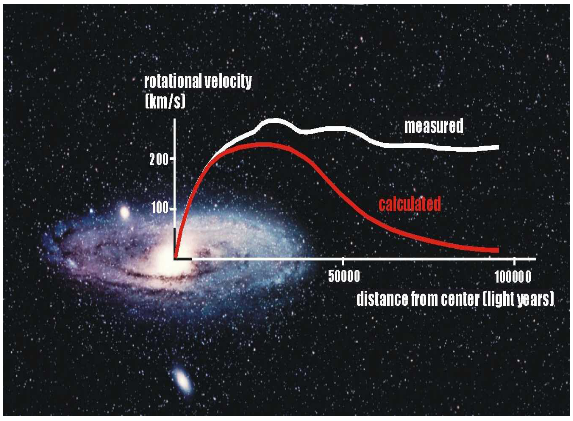

Fig. 1. Spiral galaxy rotation characteristics [13].

2.1. *The relationship between Dark Matter and the non-neutrality of the Universe*

The author of this paper believes that the problem of Dark Matter to a great extent is caused by the electrical non-neutrality of the Universe. The significant excess of positive electricity that was created in the early Universe in the form of free protons and also nuclei of deuterium, tritium, and helium and its isotopes was subjected to gravitational interaction from galaxies that had formed earlier. And here the question immediately arises: "*how could it happen that protons, repelling each other, did not disperse throughout the spaces of the Universe?*" It is hard to imagine, after all, electromagnetic interactions between particles are near about 40 orders of magnitude greater than their gravitational interactions. In the case of electric interactions in extragalactic space, all particles interact individually with each other. These interactions may ultimately compensate and in certain areas of space even cancel each other out. In the case of gravitational interactions, the mass of each particle located outside the galaxy (in this case – the mass of each proton) is affected by all the masses contained in the galaxy, all its matter, mutually adding up vectorially. It was necessary for the galaxy formation processes to occur concurrently with the gravitational formation of regions of electric charge in the form of a galactic halo. When galaxies and galaxy clusters were formed, the gravitational attraction of electric charges by galaxies, and especially galaxy clusters, began to play an important role. There was a process of creating charges around galaxies in the form of their circumgalactic halo. The situation occurred primarily around inactive galaxies and galaxy clusters, where there were no processes of emission of e-m radiation of extremely high-energy intensity (including X-rays and gamma rays) and where there were no processes of emission of matter streams in which particles moved very quickly, even with relativistic velocities. This situation is also observed in our Milky Way. Simple estimates (approximate calculations) based on the classical Newtonian theory of gravity and classical electrostatics show that it is possible to collect electric charge around the galaxy in the form of a galactic halo of enormous quantity and enormous mass. This electric halo orbits around our galaxy and, by means of centrifugal force, does not allow this charge to approach the centre (i.e., the interior) of galactic space. Different layers of the galactic halo orbit at different speeds. This galactic halo, interacting gravitationally with stars in the galaxy, is responsible to a significant extent for the much faster speed of stars further away from the galactic centre than would result from theoretical analyses based on the general theory of relativity (GTR) (Fig. 2).This situation occurs in the case of many (a lot) galaxies and galaxy clusters, primarily – inactive galaxies.

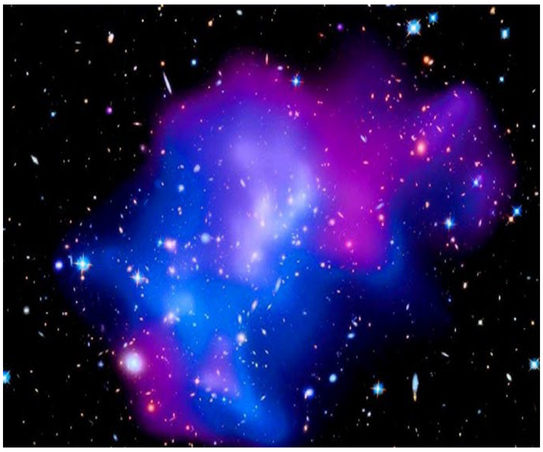

Fig. 2. The Dark Matter detected by gravitational lensing [18].

Additional matter surrounding galaxies or located in galaxy clusters is referred to as Dark Matter. The method of a direct observation of Dark Matter in the form of a galactic halo is the phenomenon of gravitational lensing – the effect of increased focusing of electromagnetic radiation of light around galaxies and galaxy clusters.

Research on the effects of Dark Matter in the Universe is intensive and advanced to the point that maps of the distribution of Dark Matter in some areas of the Universe have already been created, based on gravitational lensing [19–21]. Cosmology believed that Dark Matter is caused by small black holes, formed in the early stages of development of the Universe and huge amounts of nebulae. As research shows, however, there are too few of these types of black holes and other baryonic matter to create all or even a significant part of Dark Matter.

The author is convinced that due to the huge number of galaxies and, at the same time, also to the huge amount of unbalanced electric charge (mainly in the form of protons), the situation of creation of the galactic halo from unbalanced electric charge around galaxies and especially – galaxy clusters is common in the Universe. Not all galaxies behave as if they had Dark Matter. But many galaxies behave just like that. The author hypothesizes that Dark Matter is in large part this excess electric charge that has accumulated in the Universe around many galaxies.

But why does experimental astrophysics "not see and not detect" this charge around galaxies? What does it mean that astrophysics "does not see and not detect this great electrical charge?" Everything that is known about the Universe is known on the basis of electromagnetic radiation reaching the Earth. This radiation seems to indicate that light (i.e., e-m radiation) does not interact with the galactic halo. The fact that, as astrophysics believes, electromagnetic radiation in the Universe does not interact or interacts too weakly with the galactic halo may be an interesting physical phenomenon.

2.2. Proton Cooper pairs in the galactic halo

Here comes another amazing problem about the Universe. It is known that the Universe has been cooling down for billions of years of its expansion. The Universe has been cooling down until the extragalactic space of the Universe (areas with a limited share of active galaxies) cooled down to a temperature below 3 K. This is indicated by the relic background radiation. At this temperature below 3 K, free protons, forming to a great extent the galactic halo, experiencing on the one hand the gravitational attraction of the galactic and on the other hand mutual electrical repulsion, began to arrange themselves into Cooper pairs, just like electrons in a superconductor. In the galactic halo, there is a quite similar situation, except that Cooper pairs are created not by electrons but by protons and gravity is responsible for the attractive interaction, and not, as in a superconductor – the field of ions of its crystal lattice.

It is known that Cooper pairs that formed as two-proton systems do not interact with the external magnetic field (they interact in a special way). The galactic halo in the form of proton Cooper pairs weakly interacts with the electromagnetic radiation field. There is another effect here that is worth being aware of. It is the fact that everything that is observed on Earth and that is observed by us as coming from space outside our galaxy had to pass through our halo. It is impossible to send instruments outside our galaxy that could provide us with information about how the Universe looks outside our galaxy because the transverse dimensions of our galaxy (i.e., the smallest geometric dimensions) are over a thousand light years (LY) "thick" and only then extends the galactic halo, the thickness of which is estimated in thousands and tens of thousands of LY (and even more).

Astrophysics is currently unable to directly verify the hypothesis of the existence of Cooper pairs by protons – at least not yet. It is unknown how much of the energy from the Cosmos reaches the galactic halo of our galaxy, and then how much of this energy reaches our Milky Way, and how much of it is detected by Earth's detectors and space laboratories.

One gets the impression that astrophysics has been so focused on the existence of unusual, exotic elementary particles that it has probably subconsciously limited the possibilities of solving (partially solving) the Dark Matter problem based on typical particles.

In the following fragment, the author wants to show that the interaction of protons from the galactic halo with the gravitational field of the galaxy can be the source of Cooper pairs created from protons.

The author would like to emphasize right away that the analyses below are approximate and simplified.

In the analysis presented below, the author based himself on the Cooper's theory from 1956, i.e., almost 70 years ago [22].

The author analyses the situation of two protons interacting with each other, but practically not with other protons. This assumption seems artificial, but as a preliminary one it can be instructive. The author wants to determine the chance of such a system of two protons forming at a temperature close to zero K, depending on the evaporation potential and other physical parameters (Fig. 3).

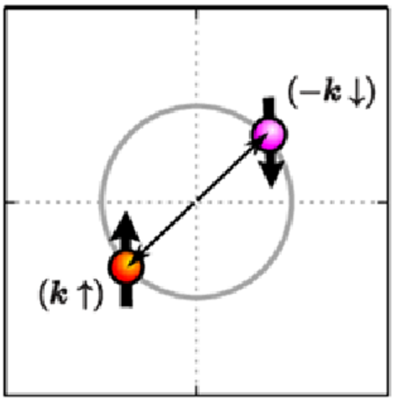

Fig. 3. The Cooper pair of two protons (based on Fig. 1 from [23]).

Let us start the analysis with the Schrodinger equation without time:

$$H\Psi(\boldsymbol{r}_1,\boldsymbol{r}_2,\sigma_1,\sigma_2)=E\Psi(\boldsymbol{r}_1,\boldsymbol{r}_2,\sigma_1,\sigma_2), \quad (1)$$

where H – the hamiltonian, E – the energy of a system of two protons at a temperature of approximately 0 K depending on the pairing potential and the effective potential energy of the gravitational field, $\boldsymbol{r}_1$ and $\boldsymbol{r}_2$ – the position of protons, and σ_1, σ_2 – the projections of the spin magnetic moment onto the direction of the gravitational field.

$$H=-\frac{\hbar^2}{2m}\nabla_1^2-\frac{\hbar^2}{2m}\nabla_2^2+V(\boldsymbol{r}_1,\boldsymbol{r}_2). \quad (2)$$

The hamiltonian consists of a kinetic part for both protons:

$$-\frac{\hbar^2}{2m}\nabla_i^2, \quad i=1,2 \quad V(\boldsymbol{r}_1,\boldsymbol{r}_2) \quad (3)$$

and from the effective potential energy (hereinafter referred to as potential) $V(\boldsymbol{r}_1, \boldsymbol{r}_2)$ of the gravitational interaction of the galaxy with protons.

Let us assume that this potential depends on the distance between protons $V(\boldsymbol{r}_1, \boldsymbol{r}_2) = V(\boldsymbol{r})$. The wave function $\Psi(\boldsymbol{r}_1, \boldsymbol{r}_2, \sigma_1, \sigma_2)$ in a simplified situation can be considered to consist of a part $\Phi(\boldsymbol{r}_1, \boldsymbol{r}_2)$ depending on the mutual distance between protons and the part $\chi(\sigma_1, \sigma_2)$ depending on the mutual position of their spins:

$$\Psi(\boldsymbol{r}_1,\boldsymbol{r}_2,\sigma_1,\sigma_2)=\Phi(\boldsymbol{r}_1,\boldsymbol{r}_2)\chi(\sigma_1,\sigma_2). \quad (4)$$

The wave function of protons as fermions is anti-symmetric. Thus:

$$\Psi(\boldsymbol{r}_1,\boldsymbol{r}_2,\sigma_1,\sigma_2)=-\Psi(\boldsymbol{r}_2,\boldsymbol{r}_1,\sigma_2,\sigma_1). \quad (5)$$

For the assumed singlet state, there is: $\chi(\sigma_1, \sigma_2) = -\chi(\sigma_2, \sigma_1)$.

The analysis is carried out for the situation in which two protons have antiparallel spins, aligned in the direction of the gravitational field. For such a situation: $\chi(\sigma_1, \sigma_2) = \text{const}$ (Fig. 3).

The spatial wave function of the two-proton system in the author's approach will have the form of:

$$\Phi(\boldsymbol{r}_1,\boldsymbol{r}_2)=\sum_{k_1,k_2}\propto_{k_1,k_2}\Psi_{k_1}(\boldsymbol{r}_1)\Psi_{k_2}(\boldsymbol{r}_2)=\frac{1}{A}\sum_{k_1,k_2}\propto_{k_1,k_2}e^{ik_1r_1+ik_2r_2}, \quad (6)$$

where $\propto_{k_1,k_2}$ are the constant coefficients in the amplitudes Ψ_{k_1},Ψ_{k_2} of the wave functions of the first and second protons of the Cooper pair.

Further analysis, in order to mathematically simplify the problem, is carried out in the coordinate system of the centre of mass of two protons ($\boldsymbol{R} = (\boldsymbol{r}_1 + \boldsymbol{r}_2)/2$; $\boldsymbol{K} = \boldsymbol{k}_1 + \boldsymbol{k}_2$) and the relative coordinate system ($\boldsymbol{r} = \boldsymbol{r}_1 - \boldsymbol{r}_2$; $\boldsymbol{k} = (\boldsymbol{k}_1 - \boldsymbol{k}_2)/2$). The simplest wave function will be used in the form of a plane wave. In the formula below, A is the normalizing factor resulting from the volume in which the interaction between protons takes place:

$$\Psi\text{k}(r)=Ae^{ikr}. \quad (7)$$

E_k is the kinetic energy of the system of both protons with the wave vector $\boldsymbol{k}$ in their system of mass centre, while E_M and p, and m are respectively: the kinetic energy of the relative motion of the pair of protons with the momentum p for their common mass $M = 2m$, in the same coordinate system of the mass centre:

$$E_k=\frac{\hbar^2k^2}{2m}, \quad E_M=\frac{p2}{2M}. \quad (8)$$

Half of the difference between the average energy of the gravitational field acting on the proton and its zero energy (theoretical value when no forces act on the protons and they are free) at their location will be considered as the E_f level:

$$E_f=\frac{\hbar^2k_f^2}{2m}, \quad (9)$$

where k_f is the wave vector corresponding to the energy E_f.

Let us assume that the potential V_0 of the gravitational field for the analysed protons is approximately constant in the region of their mutual interaction.

After tedious calculations in the centre of the mass frame, in accordance with the suggestions given in the Cooper work [22, 24], one can obtain:

$$1 = V_0 \sum_k \frac{1}{E_M + E_k + E^*}. \tag{10}$$

The energy of a system of two interacting protons is in the form of:

$$E = 2E_f - \Delta. \tag{11}$$

The interaction energy of protons in a pair in a gravitational field is reduced by the amount Δ.

Δ is the binding energy of two protons with opposite spins into a Cooper pair.

On the other hand:

$$E = (E_k - E_M) - V_0. \tag{12}$$

For a Cooper pair of two protons, assuming negligible interaction with other protons, one can obtain the formula:

$$\Delta = \left[2E_f - (E_M + E_k)\right] + V_0. \tag{13}$$

Equation (13) shows that the binding energy of two protons into a Cooper pair Δ depends linearly (it is a monotonic function) on the gravitational potential energy V_0 at the point of the pair. The masses of protons as particles are relatively large (almost two thousand times larger than the electron masses) and hence their own total kinetic energy ($E_M + E_k$) is small at temperatures close to 0 K. The fact is, however, that the proton magnetic moment, resulting from its spin, which affects its ability to form Cooper pairs, is more than a thousand times smaller for protons than for electrons.

It can be expected that the recently discovered mechanical (so-called "acoustic") vibrations of galaxies will also have an impact on the process of the proton Cooper pair formation. The action of the galaxy gravitational field, as well as the action of the halo electric field (not included in the above analysis) on the protons in the Cooper pair, causes the proton binding energy Δ to contribute to the energy E of the system of two protons forming this pair. The situation analysed above is very simplified. The above analysis does not take into account, among other things, the fact that in intergalactic space the energy E_f, which has its main source in gravitational interactions, varies depending on the mass distribution in the galaxy. It also does not take into account the spatially variable distribution of the energy of the electric field generated by protons of galactic origin, which depends on the local volume density of protons.

2.3. Conclusion to section 2

The above analytical remarks show that the merger of protons from the galactic halo into Cooper pairs can take place around galaxies or within galaxy clusters. Cooper pairs generally "do not interact" with the magnetic field. Therefore, the galactic halo, formed partly of proton Cooper pairs, can give the impression of a region that does not practically interact with electromagnetic radiation of not too high energy. The galactic halo based on protons interacts with ionizing radiation, consisting of quanta of gamma rays and high-energy X-rays.

The presented hypothesis of the proton nature of the galactic halo, where are largely created Cooper pairs, is an original idea (original achievement) of the author. This hypothesis can be an important (although probably not the only one) physical effect explaining the existence and behaviour of Dark Matter. Analyses taking into account the existence of an unbalanced electric charge in the Universe in the Dark Energy problem will be presented in the next section.

3. "The problem" with Dark Energy

3.1. Einstein's general theory of relativity

In 1915, Albert Einstein's general theory of relativity (GTR) appeared on the scene of natural science. It was a completely new and completely different theory of gravity from the traditional Newtonian one. Einstein's equation of GTR has the following form [25, 26]:

$$\boldsymbol{R}_{\mu\gamma} - \frac{1}{2}\boldsymbol{g}_{\mu\gamma}R + \Lambda \boldsymbol{g}_{\mu\gamma} = \frac{8\pi}{c^4} G \boldsymbol{T}_{\mu\gamma}, \tag{14}$$

where $\boldsymbol{R}_{\mu\gamma}$ – the Ricci curvature tensor, R – the Ricci curvature scalar, $\boldsymbol{g}_{\mu\gamma}$ – the metric tensor, $\boldsymbol{T}_{\mu\gamma}$ – the energy-momentum tensor, c – the speed of light in a vacuum, G – the gravitational constant, Λ – the cosmological constant. Metric tensor $\boldsymbol{g}_{\mu\gamma}$ describes the metric of the Riemannian mathematical manifold and is a 4 × 4 symmetric tensor (so it has 10 independent components). In turn, $\boldsymbol{R}_{\mu\gamma}$ is a tensor that is created by combinations of the second derivatives of the components of the metric tensor with respect to space-time coordinates. Given the arbitrariness in choosing the four space-time coordinates, the number of independent differential equations of the GTR can be at least six [27].

Distribution of matter in space-time is described by the energy-momentum tensor $\boldsymbol{T}_{\mu\gamma}$:

$$\boldsymbol{T}_{\mu\gamma} = (E - p)\boldsymbol{u}_\mu \boldsymbol{u}_\gamma - \boldsymbol{g}_{\mu\gamma} p, \tag{15}$$

where $\boldsymbol{u}$ – the unit vector $\boldsymbol{u}_\mu \boldsymbol{u}_\gamma = 1$, E – the spatial energy-distribution as a function of the mass distribution ρ, $E = \mathrm{f}(\rho)$, p – the pressure distribution in vacuum: $E = 0$ and $p = 0$, $\boldsymbol{R}_{\mu\gamma} = 0$, $\boldsymbol{g}_{\mu\gamma}$ – the metric tensor;

The Einstein field equation contains a parameter called the cosmological constant Λ, which was introduced by Einstein to ensure that the Universe remains static (i.e., neither expanding nor collapsing) in the general relativity description [28].

The GTR connects the geometry of space-time with the distribution of matter ρ in the Universe. GTR is one of the crowning achievements of modern science. GTR as a system of differential equations, described by (14) and (15), was long considered the most mathematically difficult scientific theory. The first to solve the GTR equations for the entire Universe were Alexander Friedmann in 1924 [29] and the priest Georges Lemaître in 1927 [30, 31].

3.2. Parameter **Ω**

From GTR, one knows that the dynamics of the Universe is primarily determined by the density ρ of matter contained in it. Most analyses of the Universe are based on the use of the average density of matter ρ.

The rate at which the expansion of the Universe proceeds and whether it will ever be stopped and reversed depends on gravity. Gravity, according to GTR, as already mentioned, depends on the amount of matter, or more precisely – on its average density ρ. In cosmological analyses, the average density of matter ρ is compared with the average critical density ρ_c, which characterizes the flat model of the Universe developed by Friedmann- Lemaître (with a zero cosmological constant Λ). The ratio of these two densities (ρ/ρ_c) is called the parameter Ω [31, 32]:

$$\Omega = \frac{\rho}{\rho_c}, \tag{16}$$

- for a closed model (so-called spherical): $\rho > \rho_c$ parameter $\Omega > 1$;
- for an open (hyperbolic) model: $\rho < \rho_c$ parameter $\Omega < 1$;
- for a flat Friedman model: $\Omega = \rho/\rho_c = 1$.

Distinction that the Universe can be: spherical, hyperbolic or flat results from the fact that the GTR equations are formulated in the so-called Minkowski spaces (for four dimensions: three spatial and one – time). Depending on the value of the matter density parameter Ω, their solution requires the use of appropriate spaces. Space is defined by relations between four variables in a given space-time.

If $\Omega < 1$, then there is not enough matter in the Universe for gravity to stop its expansion. The Universe (All) will expand forever. (It cannot be ruled out that in this case gravity would have led to an exponential expansion of matter just after the BB, and galaxies might not have come into being at all.)

If $\Omega > 1$, then gravity will stop the expansion of the Universe – All will stop and then collapse. (It cannot be ruled out that gravity would have led to the collapse of All just after the BB).

If $\Omega = 1$, then the average density of matter is exactly equal to the critical density ρ_c. (Gravity will stop the expansion of the Universe in the future, but it will not cause it to collapse.)

If one assumes that the Universe has a critical density, i.e., $\Omega = 1$, and many observation results (including those using the James Webb space telescope) indicate this, then non-baryonic Dark Matter (so-called exotic matter) gives a 6-fold greater contribution (dark non-baryons $\Omega_{DnB} = 0.253$) than baryonic dark matter (dark baryons $\Omega_{DB} = 0.042$, i.e., less than 5%) of which only 10% is luminous matter. That is, the density of luminous matter in the Universe is only 0.5% for Q = 100% !!! Non-baryonic Dark Matter is "created by particles" whose existence has not yet been confirmed.

If one assumes that the critical density of the Universe $\Omega = 1$, then [32, 33]:

- 0.5% (for $\Omega = 1$) is a baryonic luminous matter;
- 4.2% (for $\Omega = 1$) is the baryonic Dark Matter (black holes, nebulae, extinct stars,...);
- 25.3% (for $\Omega = 1$) is a non-baryonic Dark Matter, so-called exotic (unknown);
- 30.0% (for $\Omega = 1$) is the total assessed matter in the Universe;
- 70.0% (for $\Omega = 1$) is the total assessed Dark Energy in the Universe.

This means that there is more than five times more non-baryonic Dark Matter than baryonic Dark Matter. The total mass of Dark Matter present in the Universe (baryonic and non-baryonic) is near 60 times greater than the mass of luminous matter (29.5%/0.5% ≡ 59.0 times) (Fig. 4). Recent studies suggest that the amount of estimated Dark Energy is even larger than 70% [34].

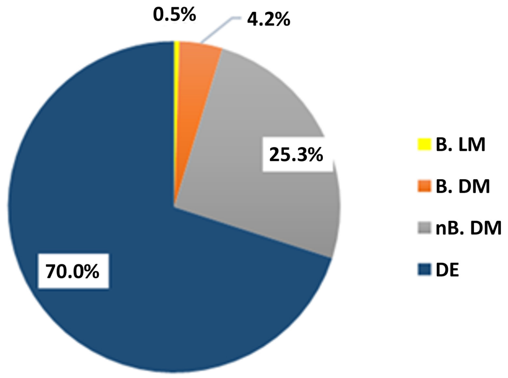

Fig. 4. Dark Matter and Dark Energy (based on [32]);
B. LM – Baryonic Luminescent Matter;
B. DM – Baryonic Dark Matter;
nB. DM – non-Baryonic Dark Mattr;
DE – Dark Energy.

An extremely important question arises: is our knowledge of the Universe correct? Everything one knows about the Universe based on its observations comes from the electromagnetic radiation recorded on Earth or from its immediate vicinity. All empirical tests used to verify its correctness concern a "sample" of matter that represents only one aspect of the structure of the Universe – baryonic matter.

In 1998, two groups of researchers led by: professor Saul Perlmutter from the University of Berkeley and professor Brian Schmidt from Harvard University announced the results of their astronomical observations and their analyses. The interpretation of these observations shows that the rate of expansion of the distant Universe is greater than predicts Hubble's law. The space between galaxy clusters and superclusters is currently accelerating its expansion faster than it was in the past. (In 2011, Saul Perlmutter, along with Brian Schmidt and Adam Riess, were awarded the *Nobel Prize in Physics* for their discoveries concerning the expansion of the Universe.) The research shows (or rather, the interpretation of this research) that there must be "something" responsible for the acceleration of the expansion of the Universe! The only candidate for this role is Dark Energy. It has been widely believed for years that it is represented in Einstein's equations by the cosmological constant Λ (14)**.**

Dark Energy has the nature of repulsive energy or the nature of "negative pressure". According to the GTR, such an acceleration of the expansion of the Universe (excessive increase in the speed of its expansion) is possible only by "violating the second law of thermodynamics", which states that the entropy of each physical system increases. Breaking the second law of thermodynamics would be a big blow to classical physics, as well as quantum physics, too!!! In that case, no form of matter (including Dark Matter) made of elementary particles, even the most exotic ones, can be responsible for the acceleration of the expansion of the Universe. This is an additional reason why the missing mass of the Universe was not previously called "mass" but "energy".

3.3. *Cosmological Principle*

It should be strongly emphasized that the parameter Ω, which defines the behaviour of the Universe in accordance with GTR depending on the density of its mass, was determined assuming the so-called Cosmological Principle. This Principle states that the Universe at large scales is homogeneous and isotropic. Later, this conclusion took a more rigorous form: all positions in the Universe are equal. This means that each observer, regardless of his position, observes a similar, in fact, the same large-scale image of the Universe [33].

Professor Adam Riess's team, as a result of very accurate and precise astronomical observations of distant type Ia supernovae, noticed that Dark Energy overcame the restraining force of gravity only about 9 billion years after the BB and caused an additional acceleration of the expansion of the Universe. And here another important question arises: why did the Universe need 9 billion years to start accelerating in its expansion?

Models belonging to the class of solutions of the GTR equations for which the Cosmological Principle applies are sometimes referred to as Friedmann, Lemaître, Robertson and Walker (FLRW) models from the first letters of the surnames of the authors of theoretical works (published after 1924) [34].

The are characterized by relatively great simplicity (for the enormous complexity of GTR). In today's works, the FLRW model is most often called the Robertson-Walker (R-W) model. Based on the R-W model, the value of the mass of the Universe and its density for $Q = 1$ was determined, which ensures its flat structure (i.e., flat geometry). It was on the basis of the R-W model that the value of the missing mass in the Universe was determined, which today is called Dark Energy and which, with the above assumptions, is 70%.

But what if the present Universe, after the BB, did not organize itself as homogeneous and the Cosmological Principle cannot be used in its description using the methods of the GTR? Testing (and even questioning) the Cosmological Principle began in the late 1970s with the discovery of voids in the Universe [33]. The further astronomical observations reached, the more inhomogeneous structures were seen. One of such inhomogeneities in the Universe are: the so-called the Great Attractor and the Great Wall in Hercules-Northern Corona (Fig. 5 and Fig. 6).

The size of the Great Attractor is estimated at about 1 billion LY.

The Great Attractor is a huge cluster of galaxies extending about 200 million LY away from the Milky Way (Fig. 5).

With its gravitational interaction, it causes the movement of galaxies from the Local Supercluster towards its centre at a speed of about 100–300 km/s. The mass of the Great Attractor is estimated at 5×10^{15} solar masses, or about 10^{46} kg.

Another, even larger concentration of matter in the Universe is the so-called the Sloan Great Wall. The size of the Sloan Great Wall is estimated at about 1.5 billion LY. In recent years, an even larger cluster of galaxies has been discovered, measuring about 4 billion LY.

The largest structure recently detected in the Universe is the Great Wall in Hercules-Corona Borealis (Fig. 6).

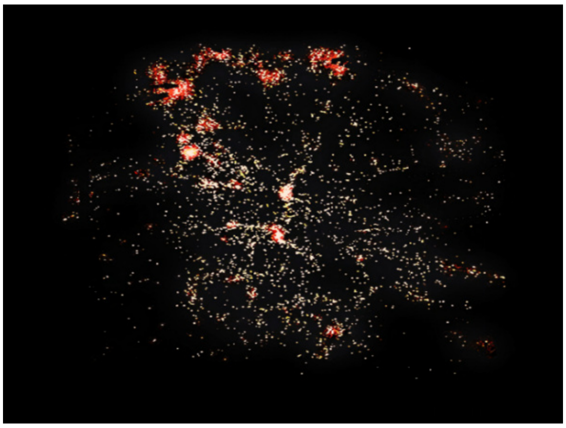

Fig. 5. The Great Attractor [35].

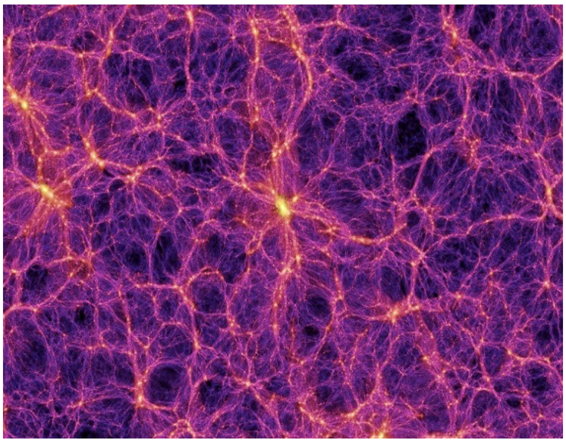

Fig. 6. The Great Wall in Hercules-Northern Corona [36].

This filament of galaxies is about 10 billion LY long and about 1 billion LY wide. It is located about 10 billion LY from our galaxy [36]. (The diameter of the Universe is estimated at 93 billion LY. The largest size of our galaxy – the Milky Way is estimated at about 100 thousand LY.)

Vast areas have also been discovered in the Universe where there is practically no matter (Fig. 7 and Fig. 8).

One such area is the so-called the Great Void – a gigantic area of empty space with a diameter of about 1 billion LY, located in the sky near the constellations of Orion and the Eridanus River [35] (Fig. 7). This is a structure that is a void, i.e., an area of empty space, practically devoid of luminous matter (galaxies and their clusters, as well as dark matter). It was discovered in 2007 by a team of American astronomers from the University of Minneapolis [36].

It is characteristic that significant inhomogeneities of the matter distribution in the Universe are observed in its distant regions. They come from areas from which light (electromagnetic radiation) reaches us after 10 or more billion years. In other words, this information comes mainly from the initial phase of the Universe development. This seems to indicate that the matter clusters in the beginning of the Universe were formed unevenly (Fig. 8) [37]. One must be aware that the Universe is a reality that is very dynamically changing in space-time. The current state of objects, especially those distant from us, is certainly different from the one observed, recorded, and analysed. In this so-called meantime, not only the position (mutual

Fig. 7. The Great Void [35].

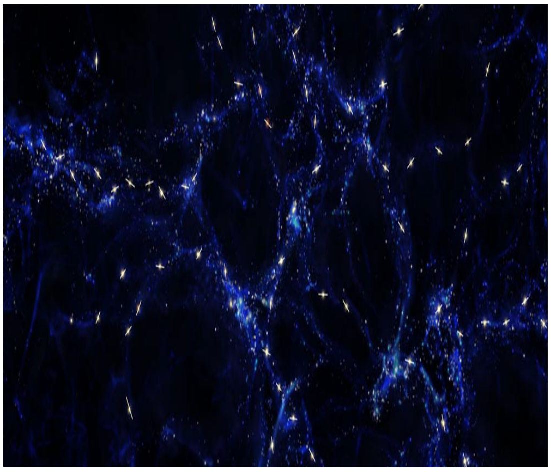

Fig. 8. Void areas in the Universe [37].

position) of galaxies and galaxy clusters has changed, but also their internal structure has changed.

A lot of new stars formed, as well as a lot of black holes, neutron stars,… Significant part of galaxies had their form of active galaxies, emitting huge amounts of energy and matter into their own galactic spaces but also often into intergalactic areas. These effects and phenomena influenced the distribution of unbalanced electric charge in the Universe.

According to some cosmologists, including: professors A. Krasinski, K. Bolejko, J. Plebanski, C. Hellaby, H. Iguchi, T. Nakamura, G. F. Ellis, T. Rothmann, R. Gautreau, and others [38–43], a much better model of the expansion of the Universe is the Lemaître-Tolman (L-T) model. The L-T model is based on the work of Lemaître from 1933 [44] and the work of Tolman from 1934 [45]. The L-T model assumes that the expansion velocity of the shell after the BB was uncorrelated with the position of the matter shell. The distribution of matter during the BB changed. The spatial distribution of shell velocities was a function of the radial variable. The initial explosion, in natural cosmological synchronization, occurred non-simultaneously – matter particles at a fixed moment of cosmological time have an age that depends on their position in the beginning phase of the BB. And this, according to the L-T model, must be taken into account in a theoretical analysis. Matter emerging later from the BB could even move at a greater speed, i.e., it could catch up and overtake (or even "collide") with matter that emerged earlier from the BB and interact with it gravitationally much more effectively.

An important modification of the L-T model was presented in 1975 by Szekeres [46]. The Szekeres model allows for radial asymmetry of the matter distribution along the BB. It seems that the Szekeres model, so far, best describes the expansion of the Universe. As a result of careful theoretical analyses, some astrophysicists using the L-T model (with zero value of Λ) for the measured infrared shifts for the cases analysed by Permutter and Schmidt teams obtain results that are theoretically consistent with observations, but without the need to take into account the "exotic" Dark Energy and without violation of the second law of thermodynamics and at a lower rate of expansion of the Universe. In the opinion of professor A. Krasinski and his colleagues, *"if the teams of professors Permutter and Schmidt had used the L-T model or the Szekeres model (instead of the R-W model) to interpret their observations, the idea of the accelerated expansion of the Universe would not have occurred to anyone"* [47]. The author shares the above opinion very strictly. In the author's opinion, the assumption of the homogeneity of the Universe, even on large volume scales, is not justified. One should not build a theoretical picture of the Universe based on the R-W model (or rather the FLRW model), which is exactly one hundred years old. The GTR contains much more important information than the theoretical analyses of the Universe based on the FLRW model allow to obtain.

The author of this paper is obliged to point out here that in the opinion of one of the greatest scientific authorities, professor Roger Penrose, the Universe develops in the form of repeating cycles, the so-called "*eons*" with unimaginably long periods (even of the order of 10^{100} years) [48]. According to professor Penrose, after the act of "creation" (in a form resembling the BB), the Universe has been developing – expanding. After a certain (unimaginably long time), matter will gradually decay until it is completely converted into field energy. The expansion will stop and the process of shrinking the Universe will begin until it completely collapses into a new singularity. After the "big collapse", there will be a "big bounce", i.e., another BB and the cycle will repeat itself. Such cycles of creation and annihilation of the Universe will repeat themselves. Professor Penrose's theory is very advanced mathematically and contains many very interesting mathematical analyses and conclusions resulting from them.

The author would like to admit that the theory of professor Penrose is not close to his own views on the evolution of the Universe. However, this does not change his huge respect for the achievements and to the person of Sir Roger Penrose.

3.4. Conclusion to section 3

If the Cosmological Principle does not apply to the Universe, then the problem of the Universe analysis based on GTR is mathematically much more difficult, because different areas of the Universe have different densities (average densities) of matter. It is very likely that the parameter Ω will lose its decisive value. The value of the

Hubble's Constant will be different for different areas of the Universe (which is already observed).

The applications of GTR to the non-uniform distribution of matter in the Universe already allow (and will allow in the future) to explain many large-scale behaviours of the Universe. Many observed phenomena can be explained without resorting to unknown particles and without violating the fundamental laws of physics

4. Conclusions

The basic hypothesis in this work is *the electrical non-neutrality of the Universe*. The author wanted to convince the scientific community that treating the entire Universe as electrically neutral is unjustified and incorrect. The Universe is endowed with a huge positive electric charge. Electrical non-neutrality is an important, and perhaps even fundamental, element of the Dark Matter problem – a problem that has been present in science for over hundred years. The electrical non-neutrality of the Universe is also a very important element of the Dark Energy problem.

The electrical nature of the Universe allows us to answer the question "*why did the Universe need 9 billion years before it began to accelerate excessively in its expansion?*" It needed this time to distribute the electric charge of the Universe among galaxies and galaxy clusters. The answer to the question *of where the repulsive force responsible for the accelerated expansion over the last 5 billion years or so comes from* is equally obvious. The reason is the electrical repulsion of galaxies coexisting with their gravitational attraction.

Please note that the above answers have nothing to do with violating the second law of thermodynamics regarding the increasing entropy of the system, which in this case is the entire Universe. It also has nothing to do with the "negative pressure" in the Universe. The unbalanced electric charge of the Universe, due to its electrical interactions, fundamentally determines its physical nature, the structure of the distribution of its matter and, consequently, its development process.

In the history of the Universe and its current perception, as well as in its mathematical description, in addition to gravitational interactions, its electrical properties and the resulting interactions of an electrical nature must be taken into account. The author is also referring to the GTR here.

The problem of the huge imbalance between matter and antimatter, created in the early Eras of the development of the Universe, remains open. The author would like to focus on this problem in subsequent publications.

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