Physical Reality and Essence of Imaginary Numbers in Astrophysics: Dark Matter, Dark Energy, Dark Space

Alexander Alexandrovich Antonov

Independent Researcher, Kiev, Ukraine

Correspondence to: Alexander Alexandrovich Antonov, telan@bk.ru

ABSTRACT

Dark matter and dark energy phenomenon which has been totally incomprehensible until very recently is explained by existence, besides our Universe, other invisible parallel universes in the hidden Multiverse. Such explanation of dark matter and dark energy phenomenon in astrophysics has become possible only after proving of the principle of physical reality of imaginary numbers discovered in mathematics 500 years ago. And the principle of physical reality of imaginary numbers has made the postulate of light speed non-exceedance in the special theory of relativity unnecessary. Therefore, all relativistic formulas in this theory should be adjusted. As follows from the adjusted relativistic formulas, we live in Multiverse rather than in Monoverse. All parallel universes of the Multiverse are mutually invisible, therefore Multiverse is called hidden. WMAP and Planck data analysis has showed that the hidden Multiverse has a quaternion structure and contains 20 - 22 parallel universes, of which 5 - 6 are adjacent to our universe, and others are further. And these parallel universes are linked by unidirectional and bidirectional portals. Some portals link the hidden Multiverse with other Multiverses, which form a dark space. The multiverses of dark space together with the hidden Multiverse form Hyperverse.

1. INTRODUCTION

In 1932-1933 Jan. Hendrik Oort [1] and Fritz Zwikky [2] discovered a new and extremely incomprehensible astrophysical object-dark matter. In 1998-1999 Saul Perlmutter [3], Brian P. Schmidt [4] and Adam G. Riess [5] discovered even more incomprehensible dark energy, for which they were awarded the Nobel Prize. These were the most outstanding discoveries of the twentieth century in astrophysics [6-9].

However, as shown below, the history of finding an explanation for the phenomenon of dark matter and dark energy, which were inexplicable because they were described by imaginary numbers, should be-

gin much earlier upon discovery of these numbers in mathematics by Scipione del Ferro, Niccolò Fontana Tartaglia, Gerolamo Cardano, Lodovico Ferrari and Rafael Bombelli [10] 500 years ago.

Although by now a perfect theory of functions of a complex variable [10] was created by works of outstanding mathematicians such as Abraham de Moivre, Leonhard Euler, Jean Le Rond D'Alembert, Caspar Wessel, Pierre-Simon de Laplace, Jean-Robert Argand, Johann Carl Friedrich Gauss, Augustin Louis Cauchy, Karl Theodor Wilhelm Weierstrass, William Rowan Hamilton, Georg Friedrich Bernhard Riemann, Oliver Heaviside, Jan Mikusiński [10] and many others, physical sense of imaginary numbers could not be proved by its founders. Moreover, this problem turned to be totally unsolvable only by mathematical means. Therefore, to solve it in accordance with the statement of Oliver Heaviside—*"Mathematics is an experimental science"*, experimental support of other exact sciences was required.

Apparently, such experimental support was supposed, first of all, to be provided by physics. However, it didn't happen. On the contrary, physical reality of imaginary numbers (physical reality of imaginary numbers, as well as real numbers, are actually reasonable to speak of only in respect of concrete numbers provided with references to units of measurement used for the corresponding parameters of physical objects) was unjustifiably denied by authors of the special theory of relativity (STR) [11-13] Joseph Larmor [14], Nobel laureate Hendrik Antoon Lorentz [15], Jules Henri Poincaré [16], Nobel laureate Albert Einstein [17], as well as by other outstanding scientists.

It was denied because in accordance with relativistic formulas of the STR mass, time and other physical quantities assumed imaginary values at superluminal speeds. However, founders of the STR did not know how to explain them. Therefore, they postulated the principle of light speed non-exceedance [18] in their theory, according to which explanation of physical sense of imaginary numbers became unnecessary.

This principle was substantiated as follows. Since according to the Lorentz-Einstein formula

$$m = \frac{m_0}{\sqrt{1-\left(v/c\right)^2}} \tag{1}$$

where m_0 is the rest mass of a moving entity (e.g. elementary particle);

m is the relativistic mass of a moving entity;

v is the velocity of a moving physical entity;

c is the speed of light;

$\lim_{v \to c-0} m(v) = +\infty$, relativistic mass m assumes, at near-light speed, values approaching to infinitely large real values. This implied that overcoming of light speed barrier required infinite big energy. And authors of the STR concluded that the overcoming of light speed barrier is impossible. Therefore, they stated that there is nothing behind the light speed barrier and we live in a Monoverse (*i.e.* the only existing universe). Consequently, imaginary mass has allegedly no physical sense at $v > c$ in the Formula (1).

However, such quite convincing, at first sight, arguments are refuted even by the simplest everyday situations. For example, inability to overcome a barrier in the form of a wall dividing adjacent rooms of your home does not mean that there is no way to get into the next room through the door. And it neither means that the adjacent room and its contents do not exist.

Therefore, the arguments about the existence of the principle of non-speeding of light convinced not all physicists. In 2011 OPERA Collaboration published results of the sensational experiment [19], which supposedly refuted the principle of light speed non-exceedance and thereby proved physical reality of imaginary numbers. However, in half a year the OPERA experiment was refuted by the ICARUS experiment [20].

But before that time, in 2008-2010 there were publications [21-25] of other experimental results, which successfully solved the problem of proving physical reality of imaginary numbers. Thus, it was proved that the explanation of their physical essence is a real problem, the search for a solution of which becomes possible and necessary. And they were proved not by physical, but by electro technical experiments. They refuted the principle of light speed non-exceedance. And since these alternative experiments can be repeated and verified in any electrical engineering and electronic laboratory, they are completely

reliable and verifiable.

It follows from the above that the problem of explanation of nature of dark matter and dark energy is interdisciplinary. Therefore, its solution requires coordinated theoretical and experimental studies of all exact sciences. However, such studies have so far been carried out only in the theory of linear electric circuits. They have been still neither confirmed nor refuted by anyone. Thus, unadjusted errors of the existing version of the STR still hamper the development of both physics and other exact sciences.

Consequently, the STR needs an appropriate adjustment, which is proposed in this article.

2. PROOFS OF PHYSICAL REALITY OF IMAGINARY NUMBERS

Before explaining how the STR should be adjusted, let us argue the necessity of such adjustments. For this purpose we present one of evidence of physical reality of imaginary numbers [21-35], obtained as a result of analysis of oscillatory processes in linear electric LCR-circuits. This is a proof [31-35] applying the law of Ohm [36], known to every educated person, in the interpretation proposed by Charles Proteus Steinmetz [37], which is usually called a symbolic method for calculation of electric LCR-circuits. Besides, the proof is not only theoretical, but also experimental, as it is confirmed by the results of daily practical activities of all electric and radio engineers.

Its essence consists in the following. Value of the complex resistance of the LCR-circuit always depends on the frequency. Therefore, if it turns out that this circumstance is confirmed experimentally, imaginary inductive and capacitive reactances will have to be recognized as physically real. Otherwise they will have to be recognized as imaginary and in fact, *i.e.* actually physically non-existent not only by name, but also in nature.

All engineers have known for more than a hundred years that magnitude of complex resistance of the LCR-circuits changes with the frequency. Using this knowledge, engineers create, by changing frequency characteristics of electric LCR-circuits, a variety of filters, without which existence of radio engineering, telecommunication, television, radiolocation and other exact sciences would not have been possible.

This means that the so-called imaginary inductive and capacitive reactances are actually as real as resistance of resistors. Consequently, each measurement that confirms the validity of Ohm's law in Steinmetz's interpretation proves physical reality of imaginary numbers.

Thus, this was the first time in science Ohm's law in the interpretation of Steinmetz allowed for both proof of physical reality of imaginary numbers and explanation of their physical sense. And it means what has become possible to explain physical essence and other imaginary numbers which aren't less real, than the real numbers.

The proofs given above quite convincingly prove physical reality of imaginary numbers of any physical nature. However, this is not enough for understanding physical sense of imaginary numbers. To understand it, the imaginary numbers measuring parameters of the corresponding objects and phenomena should be seen, heard, or otherwise felt. Unfortunately, people do not have the necessary sense organs for this.

But despite the fact that people are unable to hear infra-and ultrasounds, to see radio waves and cosmic rays, to feel magnetic field and X-ray radiation and to touch atoms and molecules, they have got evidence of their actual physical existence and understood their physical sense with the help of devices that can transform information that is inaccessible to our senses into accessible information.

There are a lot of such devices in any laboratory. It is beyond any doubt that devices for registration of imaginary physical entities, measured by any imaginary numbers will also be created sooner or later. Herewith, devices for measuring electric engineering imaginary quantities have long been created.

Therefore, the principle of physical reality of imaginary numbers has to be recognized as general scientific and all theories and hypotheses in exact sciences have to be adjusted in accordance with it.

3. EXPLANATION OF PHYSICAL ESSENCE OF IMAGINARY NUMBERS IN THE SPECIAL THEORY OF RELATIVITY

And now, using the example of the special theory of relativity, we will show how far from a truth cer-

tain theories and hypotheses can be if they ignore the physical reality of imaginary numbers.

For more than 100 years—since its inception and up to the present day, SRT has been criticized [38-41] not always fair, often even politically biased, but sometimes true and irrefutable.

For example, the above-described studies of oscillatory processes in linear electric circuits both proved the general scientific principle of physical reality of imaginary numbers and refuted the principle of light speed non-exceedance [42] and its hypothesis of the Monoverse in the STR.

Moreover, they have been refuted by previously unknown experiments that are decisive arguments (driven by the same reasons, Cardinal Richelieu ordered in the Thirty Years' War to inscribe upon cannons the following text: *"Ultima ratio regum"* i.e. the last argument of king) determining the fate of a relevant theory in science, rather than by certain postulates (*i.e.* unproved assumptions), as is often practiced in modern physics. These experiments cannot be refuted by any postulates. But only actual experiments are meant hear, rather than so-called "thought experiments" in the STR being just reasoning which can turn out to be erroneous.

Albert Einstein stated in this regard: *"Truth is what stands the test of experience"*.

As a result of this approach it was found out that in reality we actually live in the invisible Multiverse [43-46], rather than in the Monoverse. But the invisible Multiverse does not correspond to any of the numerous interesting and unusual hypotheses proposed to date [47-55], all of which are, however, unverifiable (while the hypothesis of hidden Multiverse, as shown below, is verifiable), *i.e.* such that can neither be confirmed nor disproved experimentally, now or ever.

Moreover, since the principle of physical reality of imaginary numbers proven theoretically and experimentally refutes the principle of light speed non-exceedance in the STR, relevant physical quantity values in relativistic formulas, such as, for example,

$$\Delta t = \Delta t_0 \sqrt{1 - (v/c)^2} \tag{2}$$

$$l = l_0 \sqrt{1 - (v/c)^2} \tag{3}$$

where Δt_0 is the rest time of a moving entity;

Δt is the relativistic time of a moving entity;

l_0 is the rest length of a moving entity;

l is the relativistic length of a moving entity;

Should be recognized as physically existent also for the range of hyperluminal speeds, and their physical sense, failed to be explained by authors of the STR, should be explained.

However, it could not be explained within the existing version of the STR, since functions (1), (2), (3) of the speed of motion v vary in different ways in the ranges $v > c$ and $v < c$, which contradicts to the first postulate of the STR. Therefore relativistic formulas of the existing version of the STR have to be recognized as incorrect (or rather partially true only for our universe but not for the Multiverse as a whole).

Explanation of the formulas in the range of hyperluminal speeds $v > c$ would be possible and consistent with their explanations in the range of subluminal speeds $v < c$, if adjusted relativistic STR formulas corresponding to them will take the following form

$$m = \frac{m_0 i^q}{\sqrt{1 - (v/c - q)^2}} = \frac{m_0 i^q}{\sqrt{1 - (w/c)^2}} \tag{4}$$

$$\Delta t = \Delta t_0 i^q \sqrt{1 - (v/c - q)^2} = \Delta t_0 i^q \sqrt{1 - (w/c)^2} \tag{5}$$

$$l = l_0 i^q \sqrt{1 - (v/c - q)^2} = l_0 i^q \sqrt{1 - (w/c)^2} \tag{6}$$

where $q = \lfloor v/c \rfloor$ is the discreet "floor" function of argument v/c;

$w = v - qc$ is the local velocity for each universe, which can take values only in the range $0 \le w < c$;

v is the velocity measured from our universe, which can therefore be called tardyon velocity;

Other relativistic formulas can be adjusted in a similar manner.

Albert Einstein did not exclude the adjustment of the STR in future. He wrote: "*No single idea, which I would be sure that it will stand the test of time*".

4. EXPLANATION OF PHYSICAL ESSENCE OF IMAGINARY NUMBERS IN ASTROPHYSICS

Since modern astrophysical theories and hypotheses are largely based on the theory of relativity, the revision of the STR in this article inevitably entails the revision of relevant astrophysical conceptions.

4.1. Hidden Multiverse

It follows from the adjusted relativistic formulas of the STR (4), (5) and (6) that the value q can take different integer values (it takes non-integer values in portals, in which value q varies by one from their entry to their exit), which correspond to different universes. So, the value $q = 0$ corresponds to our universe (for which $i^0 = 1$), and the value $q = 1$ corresponds to another universe (for which $i^1 = i$), which is invisible for us when $v > c$, as it is beyond the horizon of events. Stephen William Hawking wrote about imaginary time in this universe as follows: "*Imaginary time is a new dimension, at the right angles to ordinary, real time*". His studies have confirmed the validity of the hypothesis of the hidden Multiverse considered below.

The universe corresponding to $q = 1$ shall be for definiteness referred to as tachyon, contains tachyons (by which subatomic particles, moving at a speed exceeding light speed, are meant. And therefore, most physicists believe that they should not exist in nature, by which erroneous hypothesis of the Monoverse corresponding to the STR is understood, since they violate the principle of causality. However since, as shown in this article, tachyons are in tachyon universe or antiverse, rather than in our tardyon universe, they do not violate the principle of causality) [56-63]. For similar reasons, our universe is called tardyon. Thus, the value $q = 2$ corresponds to the tardyon antiverse (for which $i^2 = -1$), the value $q = 3$ corresponds to the tachyon antiverse (for which $i^3 = -i$), the value $q = 4$ corresponds to another (since it is further shown that there are about twenty such universes) tardyon universe (for which $i^4 = 1$), the value $q = 5$ corresponds to another tachyon universe (for which $i^5 = i$), etc. Such an invisible Multiverse is called hidden.

Ultimately, all these mutually invisible tardyon and tachyon universes and antiverses form the structure of a hidden Multiverse in the form of a screw ring either closed (Figure 1) or unclosed (Figure 2 and Figure 3). If the ring is closed (Figure 1), the hidden Multiverse is obviously single in nature. If the ring is unclosed (Figure 2 and Figure 3), the hidden Multiverse is not the only one in nature and through portals it is connected with other Multiverses: twice with the same Multiverse (Figure 2) or with two other different Multiverses (Figure 3). Thus, they together form a larger structure, which shall be referred to as Hyperverse.

And if in the Formulas (4), (5), (6) the value q is understood as an additional spatial dimension (like numbers of apartments in an apartment building, where each apartment has its three spatial dimensions), then it can be stated that the four-dimensional space of the hidden Multiverse is described by a function $f_q(x, y, z) + iq$, in which x, y, z are the coordinates of the material content of the corresponding parallel (since, despite their infinity, they do not intersect) universe, and q is the coordinate of this the universe in the fourth dimension.

And in this fourth dimension, the parallel universes, continuously drifting with respect to each other, touch each other all the time, and even infrequently plunge into each other, forming a multitude of portals (which have nothing to do with "wormholes" in the general theory of relativity) [64, 65] which are bidirectional and in Figures 1-3 are denoted by single two-sided arrows). Portals on Earth are numerous so-called anomalous zones [66]. On Earth they can be on, above and below its surface, as well as on the surface of rivers, lakes, seas, oceans and in their depths. Anomalous zones can have different sizes and manifest themselves differently. Neighbouring universes can exchange their material contents including
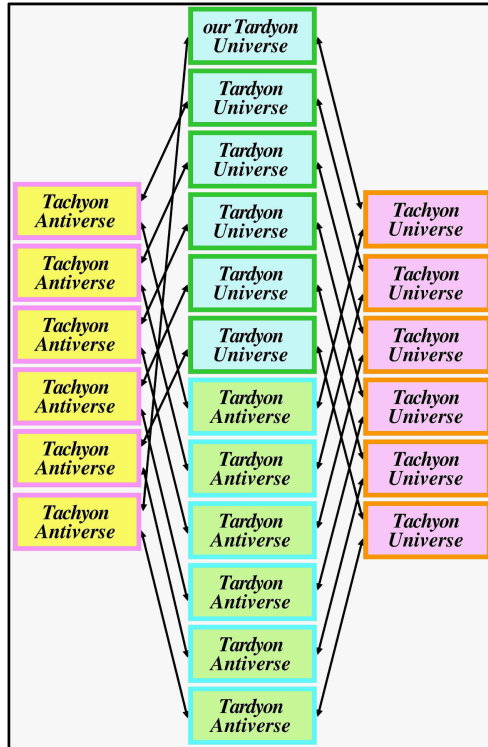
Figure 1. The structure of the hidden Multiverse corresponding to the principle of physical reality of complex numbers.
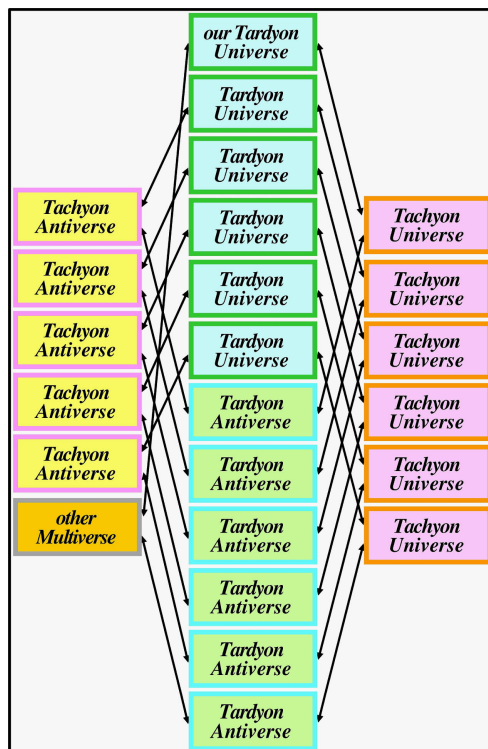

Figure 2. Another structure of the hidden Multiverse corresponding to the principle of physical reality of complex numbers.
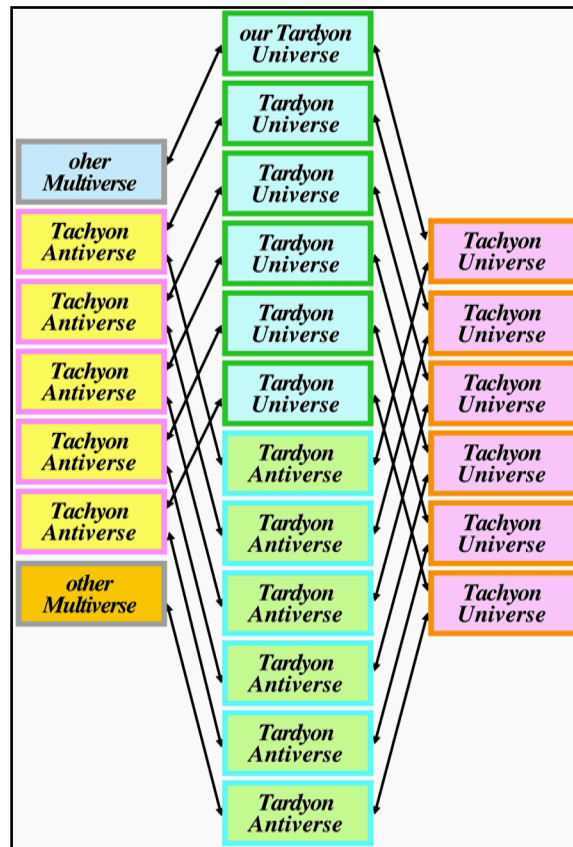
Figure 3. One more structure of the hidden Multiverse corresponding to the principle of physical reality of complex numbers.

their living inhabitants through the portals. Therefore, mass of parallel universes of the hidden Multiverse should have been substantially averaged over billions of years of its existence.

4.2. Explanation of Dark Matter and Dark Energy

Data obtained by the WMAP [67] and Planck [68] spacecrafts allow us to specify the structure of the hidden Multiverse. According to the WMAP spacecraft data the entire universe (in fact, the entire hidden Multiverse) is composed of 4.6% baryonic matter, 22.4% dark matter and 73.0% dark energy. However, according to the later data of the Planck spacecraft, the entire universe (again, in fact, the entire hidden Multiverse) is composed of 4.9% baryonic matter, 26.8% dark matter and 68.3% dark energy.

Consequently, the total mass-energy of dark matter and dark energy is more than twenty times greater than the mass-energy of our visible universe. It has been inexplicable until very recently what dark matter and dark energy, actually, are. It has been as well completely incomprehensible why dark matter and dark energy are absolutely invisible in any range of electromagnetic radiation. These physical substances have been called dark due to their incomprehensibility. Stephen William Hawking wrote in this regard: *"The missing link in cosmology is the nature of dark matter and dark energy"*.

In fact, dark matter and dark energy can only conditionally be called "incomprehensible". This is due to the fact that they are inexplicable within the Monoverse hypothesis corresponding to the existing version of the STR, which, as is shown above, is not totally correct. But dark matter and dark energy phenomenon explanations have been so far searched for only in terms of this version. Albert Einstein's assertion is quite appropriate in this regard: *"Insanity: doing the same thing over and over again and expecting different results"*.

Once we give up on the described limitations and get to consider the phenomenon of dark matter and dark energy within the hypothesis of the hidden Multiverse corresponding to the adjusted version of the STR, it is no longer necessary to seek for its explanation. It is apparent [69-79]:

- dark matter and dark energy are just other names for other parallel universes of the hidden;
- Multiverse, except our tardyon universe;
- dark matter is parallel universes of the hidden Multiverse adjacent to ours;
- dark energy is other parallel universes of the hidden Multiverse, except our universe and universes adjacent to ours;

Therefore persistent attempts to detect dark matter and dark energy in the microcosm of our visible universe force us to recall the words Confucius: "*The hardest thing of all is to find a black cat in a dark room, especially if there is no cat.*"

The above explanation of the dark matter and dark energy phenomenon makes it possible to concretize the structure of the hidden Multiverse. Indeed, considering the masses of different parallel universes in the hidden Multiverse to be equal with the high degree of accuracy, we can determine:

- how many parallel universes form a hidden Multiverse. According to the WMAP spacecraft data, specified above, their number is $100\%/4.6\% = 21.74$. And according to the Planck spacecraft data their number is $100\%/4.9\% = 20.41$. Consequently, their actual number is supposedly $20\cdots22$.
- how many parallel universes correspond to the phenomenon of dark matter. According to the WMAP spacecraft data their number is $22,4\%/4.6\% = 4.87$. And according to the Planck spacecraft data their number is $26.8\%/4.9\% = 5.47$. Consequently, their actual number is likely equal 5 or 6.
- how many parallel universes correspond to the phenomenon of dark energy. According to the WMAP spacecraft data their number is $73.0\%/4.6\% = 15.87$. And according to the Planck spacecraft data their number is $68.3\%/4.9\% = 13.94$. Consequently, their actual number is supposedly $14\cdots16$.

And immediately attracts attention the discrepancy between the results of calculations and the corresponding shown in **Figures 1-3** assumed structures of the latent Multiverse, which cannot be explained by the inaccuracy of the WMAP and Planck spacecraft measurements, since the discrepancy is too great. Other parallel universes adjacent to our universe turned out to be five or six rather than two. But the number does not fit into the structure shown in **Figures 1-3**, as it can in no way be explained.

This suggests that there was some error in the previous reasoning. The error lies in the fact that we assumed, for simplicity, only one additional dimension in the hidden Multiverse and, consequently, its correspondence to physically real complex numbers containing only one imaginary unit.

And in order that our universe was next to six other universes, namely three tachyon universes and three tachyon antiverses, there should be three extra dimensions q,r,s determining their position in space. Consequently, space of the hidden Multiverse should be six-dimensional. Its structure would correspond to quaternions $\sigma + i_1\omega_1 + i_2\omega_2 + i_3\omega_3$, *i.e.* hyper-complex numbers [80], containing just three imaginary units i_1,i_2,i_3 which are connected by the following relations

$$i_1^2 = i_2^2 = i_3^2 = 1 \tag{7}$$

$$i_1 i_2 i_3 = i_2 i_3 i_1 = i_3 i_1 i_2 = -1 \tag{8}$$

$$i_1 i_3 i_2 = i_2 i_1 i_3 = i_3 i_2 i_1 = 1 \tag{9}$$

Thus, quaternion space of the hidden Multiverse would be described by the formula

$$f_{q,r,s}(x,y,z) + i_1 q + i_2 r + i_3 s$$

where function $f_{q,r,s}(x,y,z)$ determines distribution of material contents in a corresponding parallel universe with coordinates $i_1 q, i_2 r, i_3 s$.

Therefore, the relativistic formulas of the STR (4), (5), (6) indicated above should be adjusted again as follows

$$m = \frac{m_0 (i_1)^q (i_2)^r (i_3)^s}{\sqrt{1 - [v/c - (q + r + s)]^2}} = \frac{m_0 (i_1)^q (i_2)^r (i_3)^s}{\sqrt{1 - (w/c)^2}} \qquad (10)$$

$$\Delta t = \Delta t_0 (i_1)^q (i_2)^r (i_3)^s \sqrt{1 - [v/c - (q + r + s)]^2}$$
$$= \Delta t_0 (i_1)^q (i_2)^r (i_3)^s \sqrt{1 - (w/c)^2} \qquad (11)$$

$$l = l_0 (i_1)^q (i_2)^r (i_3)^s \sqrt{1 - [v/c - (q + r + s)]^2}$$
$$= l_0 (i_1)^q (i_2)^r (i_3)^s \sqrt{1 - (w/c)^2} \qquad (12)$$

where q is the total number of parallel universes, penetration into which, as we move away from our tardion universe, is made through portals, corresponding to the imaginary unit i_1;

r is the total number of parallel universes, penetration into which, as we move away from our tardion universe, is made through portals, corresponding to the imaginary unit i_2;

s is the total number of parallel universes, penetration into which, as we move away from our tardion universe, is made through portals, corresponding to the imaginary unit i_3;

$w = v - (q + r + s)c$ is the local velocity for corresponding universe, which can take values only in the range $0 \leq w \leq c$.

Other relativistic formulas of the STR can be adjusted in a similar manner.

Ultimately, all these mutually invisible tardyon and tachyon universes and antiverses form the structure of a hidden Multiverse in the form of a screw ring either closed (**Figure 1**) or unclosed (**Figure 2** and **Figure 3**). If the ring is closed (**Figure 1**), the hidden Multiverse is obviously single in nature. If the ring is unclosed (**Figure 2** and **Figure 3**), the hidden Multiverse is not the only one in nature and through portals it is connected with other Multiverses: twice with the same Multiverse (**Figure 2**) or with two other different Multiverses (**Figure 3**). Thus, they together form a larger structure, which shall be referred to as Hyperverse.

4.3. Discovery of Dark Space

Quaternion structure of the hidden Multiverse [81] in the form of a close screw ring corresponding to the Formulas (7), (8) and (9) is shown in **Figure 4**, on which, however, it is conditionally represented as an open screw ring, for simplicity. Therefore in such conditionally opened screw structure our tardion Universe is represented twice–not only as the beginning, but also as the end of counting of the parallel Universes.

As can be seen, the difference of the structure shown in **Figure 4** from the structures shown in **Figures 1-3** is the availability of several different tachyon universes and antiverses in it, corresponding to the three imaginary units i_1, i_2, i_3. Another difference, caused by the relations (7), (8), (9), connecting imaginary units i_1, i_2, i_3, is the availability in the structure of the Multiverse not only bidirectional portals corresponding to the Formula (7) and denoted by two-sided arrows, but also unidirectional portals, corresponding to the Formulas (8), (9) and denoted by one-sided arrows.

The principle of operation of bidirectional portals in this structure can be explained in the following way (**Figure 5**). It follows from the Formula (7) $i_1^2 = -1$ that moving through a bidirectional portal i_1 from a tardyon universe to a tachyon universe i_1 and thence through another bidirectional portal i_1, we get into a tardyon antiverse. It also follows from the Formula (7) $i_1^2 = -1$ that moving through a bidirectional portal i_1 from a tardyon antiverse to a tachyon antiverse i_1 and thence through another bidirectional portal i_1, we get into another tardyon universe. The Formula (7) $i_1^2 = -1$ also implies that moving through a bidirectional portal i_1 from another tardyon universe to a tachyon antiverse and thence through another bidirectional portal i_1, we get into a tardyon antiverse. Finally, the Formula (7) $i_1^2 = -1$
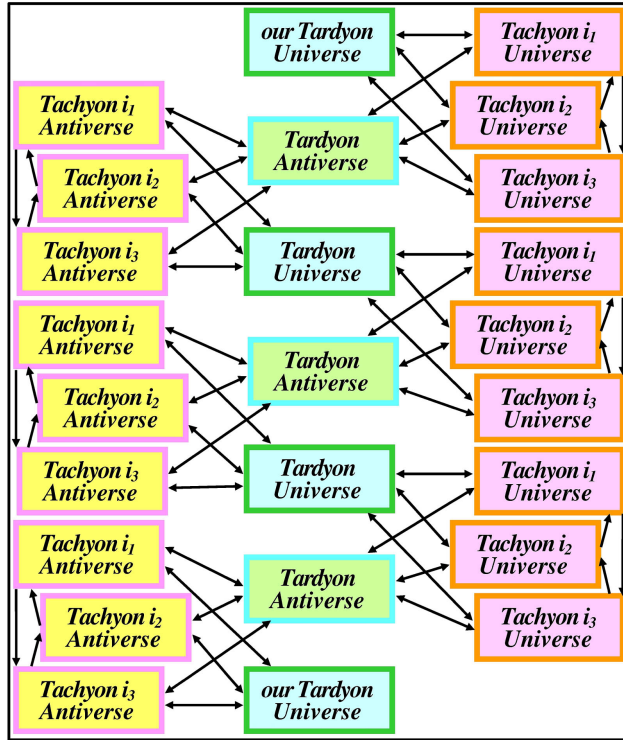
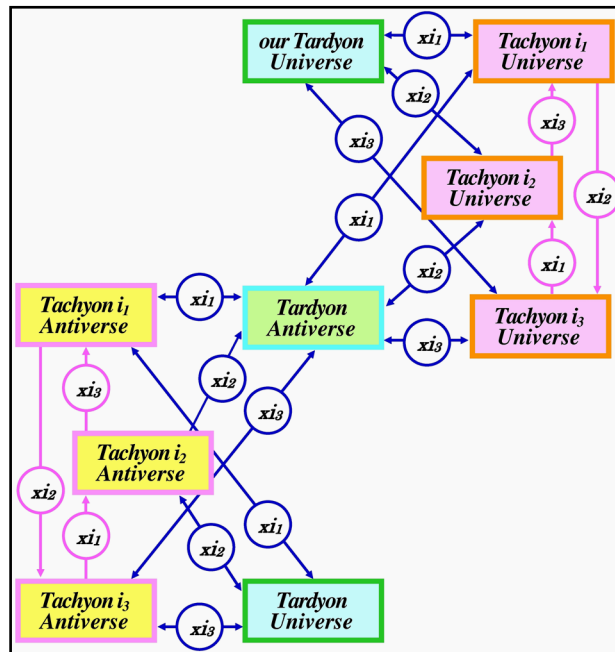**Figure 4.** Quaternion structure of the hidden Multiverse containing twenty four parallel universes.

Figure 5. Portal operational algorithm.

implies that moving through a bidirectional portal i_1 from a tardyon antiverse to a tachyon universe i_1 and thence through another bidirectional portal i_1, we get into a tardyon universe.

Formulas (7) $i_2^2 = 1$ and $i_3^2 = 1$ are explained similarly.

To explain the principle of operation of unidirectional portals, Formulas (8) and (9) shall be rewritten

in a somewhat different form

$$i_1 i_2 = i_3 \qquad (13)$$

$$i_2 i_3 = i_1 \qquad (14)$$

$$i_3 i_1 = i_2 \qquad (15)$$

$$i_1 \left(-i_3 \right) = i_2 \qquad (16)$$

$$i_2 \left(-i_1 \right) = i_3 \qquad (17)$$

$$i_3 \left(-i_2 \right) = i_1 \qquad (18)$$

Therefore it follows from the Formula (13) $i_1 i_2 = i_3$ that moving from a tardyon universe to a tachyon universe i_1 through a bidirectional portal i_1 and then through unidirectional portal i_2, we get into a tachyon universe i_3 (**Figure 5**). And as a result of moving from a tardyon antiverse to a tachyon antiverse i_1 through a bidirectional portal i_1 and then through unidirectional portal i_1, we get into a tachyon antiverse i_3.

Formulas (14) $i_2 i_3 = i_1$ and (15) $i_3 i_1 = i_2$ are explained similarly.

The Formula (16) $i_1 \left(-i_3 \right) = i_2$ is identical to the Formula (14) $i_1 = i_2 i_3$. Therefore, it implies the above-described result. The Formula (17) $i_2 \left(-i_1 \right) = i_3$ is identical to the Formula (15) $i_2 = i_3 i_1$. Therefore, it implies the above-described result. The Formula (18) $i_3 \left(-i_2 \right) = i_1$ is identical to the Formula (13) $i_3 = i_1 i_2$ и $i_3 = i_1 i_2$. Therefore, the results described above follow from them.

All the transitions are shown in **Figure 4**.

A hidden Multiverse having such a structure could be the only one in nature, if its existence were confirmed by experimental data. However, the structure of the hidden Multiverse does not correspond to the data obtained by WMAP and Planck spacecrafts, as their mathematical analysis has shown that the structure contains twenty to twenty-two, rather than twenty-four parallel universes. Therefore, the data obtained by WMAP and Planck spacecrafts correspond to a partially open screw structure of the hidden Multiverse connected to other Multiverses through portals, forming together a Hyperverse. In other words, Hyperverse is a multidimensional (supposedly infinite dimensional) universum, analogous to a huge city in which our three-dimensional visible universe is just one of the apartments. This fact allows us to assert that other invisible Multiverses, besides our hidden Multiverse, contained in the Hyperverse, form dark space. Some possible structures for the hidden Multiverse are presented below.

Figure 6 presents a structure of the hidden Multiverse containing twenty parallel universes, of which five parallel universes are adjacent to our tardyon universe. In this structure Hyperverse is formed by the hidden Multiverse and two other Multiverses. One of the two Multiverses replaces three of parallel universes in the hidden Multiverse, and another one replaces its one parallel universe.

Figure 7 presents a structure of the hidden Multiverse containing twenty one parallel universes, of which six parallel universes are adjacent to our tardyon universe. In this structure Hyperverse is formed by the hidden Multiverse and two other Multiverses, one of which is connected twice with the hidden Multiverse.

Figure 8 presents a structure of the hidden Multiverse containing twenty two parallel universes, of which six parallel universes are adjacent to our tardyon universe. In this structure Hyperverse is formed by the hidden Multiverse and two other Multiverses.

Figures 6-8 show multitude of parallel universes of the hidden Multiverse forming dark matter and dark energy. They also demonstrate multitude of other Multiverses which form a Hyperverse together with the hidden Multiverse. The multitude of the other Multiverses constitutes dark space referred to as such because it is invisible and unknown just like dark matter and dark energy.

In **Figure 9(a)**, which repeats **Figure 7** and **Figure 8** in simplified form, it is shown that universes of dark matter, dark energy and dark space differ from each other with just one parameter-different remoteness from our tardyon universe. And the closest to our tardyon universe are the universes of dark matter. Universes of dark energy are located further from us. And Multiverses of dark space is even further-already outside the hidden Multiverse. Therefore, dark space has not been discovered until now. And
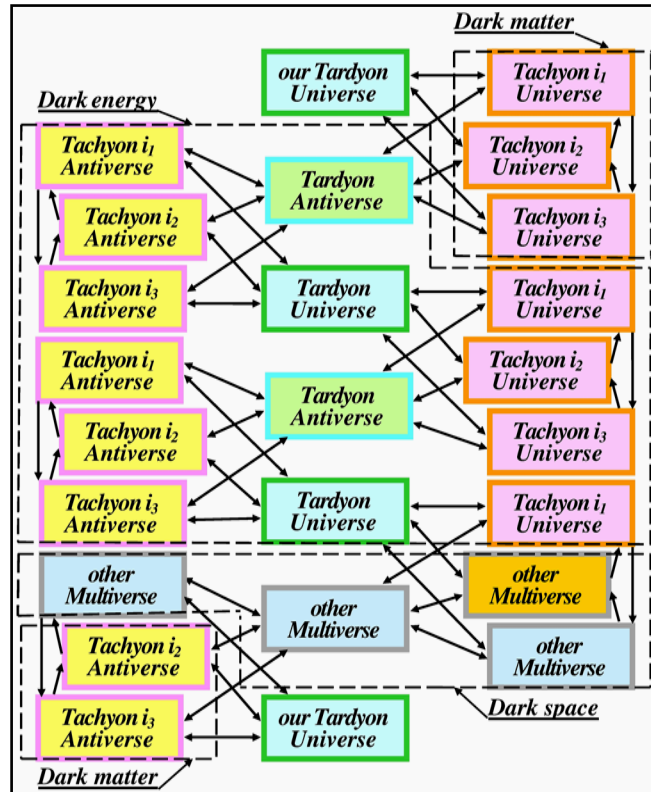
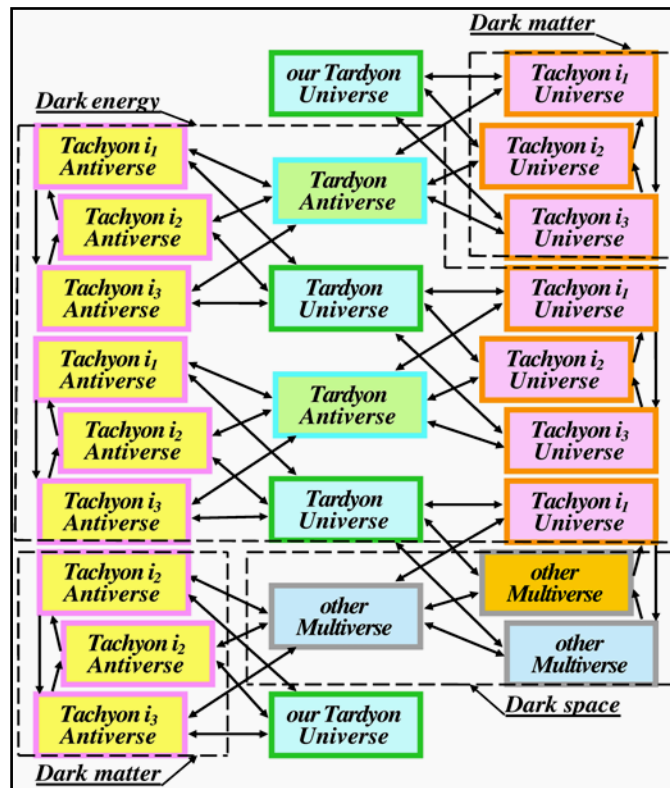**Figure 6.** Quaternion structure of the hidden Multiverse containing twenty parallel universes.

Figure 7. Quaternion structure of the hidden Multiverse containing twenty one parallel universes.
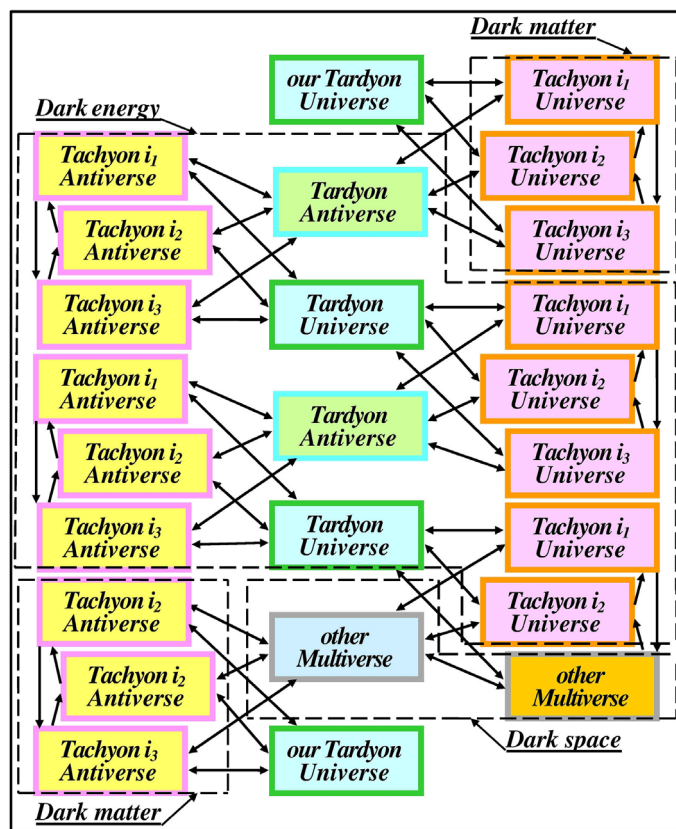
Figure 8. Quaternion structure of the hidden Multiverse containing twenty two parallel universes.
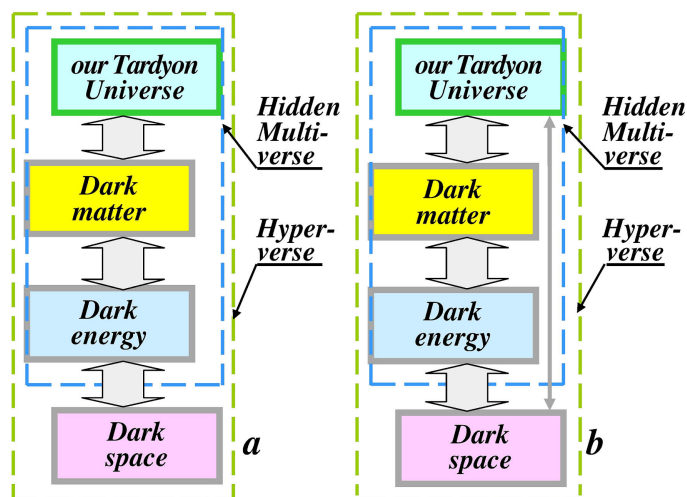
Figure 9. Location of dark matter, dark energy and dark space in Hyperverse in relation to our tardyon universe.

in **Figure 9(b)**, which repeats **Figure 6** in simplified form, it is shown that besides the portals specified **Figure 9(a)** between our universe and the universes of dark matter, there can be additional portals between our universe and one of the universes of dark space. This circumstance, therefore, the study of the dark space, and thus the proof of its existence, makes it really possible.

When analysing **Figures 6-8**, the question may also arise-why is our universe called tardyon, and not

one of the tachyon universes and antiverses or not tardyon antiverse? And this is explained by the fact that according to the data of WMAP and Planck spacecrafts, our universe should have five or six neighboring universes, but such a number of neighboring universes, as seen in Figures 6-8, have only tardyon universes and antiverses. And the tardyon antiverse is functionally the same as the tardyon universes. But if our universe is called antiverse, then it will be necessary to call matter antimatter, time-antitime, etc. It is clear that this is not necessary.

It is obvious that besides the structures of our hidden Multiverse given in Figures 6-8, there is a very large number of other structures which also correspond to the observations of the WMAP and Planck spacecrafts. It is evident that additional astrophysical investigations are needed to clarify the actual structure of our hidden Multiverse.

4.4. Antimatter

Antimatter is another astrophysical object that is even more obscure, than dark matter and dark energy [82-88].

Indeed, on the one hand, there should have been equal amount of matter and antimatter after the Big Bang in accordance with its theory. But, on the other hand, once matter and antimatter had been formed, they should have been annihilated. In this case our universe should not exist. Nevertheless, it exists, because we exist.

Common sense suggests that, this is the reason why matter and antimatter cannot be in the same universe and must exist in different universes in different dimensions. Consequently, existence of antimatter also proves existence of Multiverse.

The easiest way, under such circumstances, would be to assume that antimatter does not exist at all. But scientists managed to synthesize antimatter, as well as detect it in some natural phenomena (in cosmic rays, in Earth atmosphere after a storm, etc.). But the synthesized antimatter was obtained in a miniscule amount and existed for a very short time (for example, in 1995 CERN achieved a sensational success of that time, having obtained nine antihydrogen atoms, which existed approximately 40 nanoseconds). For example, in 1995 CERN achieved a sensational success of that time, having obtained nine antihydrogen atoms, which existed approximately 40 nanoseconds. Besides, synthesis of the antimatter was extremely expensive. One gram of antihydrogen would cost 662.5 trillion dollars.

However, most importantly, such studies do not give answer to the question of where antimatter can be found in large quantities, *i.e.* in the form of antiverses. And again, if we give up on the Monoverse hypothesis, the answer to this question becomes quite obvious: antimatter is in antiverses of the hidden Multiverse.

The same answer is when we explain existence of tachyons and phenomenon of dark matter and dark energy. Moreover, there are even several pairs of universes-antiverses in the hidden Multiverse, as shown in Figures 6-8. And their non-annihilation is explained by alternation of tardyon and tachyon universes and antiverses in multidimensional space in order determined above.

4.5. Verifiability of the Hypothesis of the Hidden Multiverse

Thus, the hypothesis the hidden Multiverse so simply and convincingly decides many of extremely important problems of astrophysics which were still remaining unresolved that according to criterion "Occam'srazor" natural is the assumption of its physical reality.

This is despite the fact that all other hypotheses of the Multiverse [47-55] are unverifiable. That's why so many scientists are sceptical about the idea of the Multiverse: why study something that does not exist. In their view, efforts to uncover actual secrets of nature are much more important [89-91].

However, the hypothesis of the hidden Multiverse is verifiable. It can not only receive experimental confirmations, it already has them [92]. In fact:
- Firstly, as shown above, phenomenon of dark matter and dark energy, which are just other names for a large number of other, except our universe, parallel universes of the hidden Multiverse, is experimental confirmation of its existence.

- Secondly, its existence is confirmed by numerous experiments at the Large Hadron Collider and other subatomic particle accelerators, in which there was a mass defect, *i.e.* the total mass of elementary particles was greater before acceleration than near the point of astrophysical singularity when. Results of these experiments can be explained by formation of tachyons that, having overcome the light speed barrier, disappeared in tachyon universes and/or tachyon antiverses, e.g., as a result of formation of short-term micro portals, similar to formation of macro portal in the episode with the Eldridge destroyer.
- Finally, geophysical studies of portals, which are numerous on the Earth so-called anomalous zones [67], will the most convincing experimental evidence [93, 94] of the hidden Multiverse. It is possible to assume that their research is relatively safe, since according to the law of communicating vessels, parameters of environment in areas before and beyond the portals should be almost identical. Therefore, if on Earth at least one portal has been open in an outer space, Earth was left without the atmosphere and the hydrosphere long ago. Perhaps it was once happened on Mars.

Therefore, the hypothesis of the hidden Multiverse, in contrast to other hypotheses of the Multiverse mentioned herein, has every reason to be called a theory.

5. DARK DIMENSIONS

From stated above the obvious question follows–what is the physical sense of imaginary numbers in other cases, such as, for example, in the Euler's formula $e^{ix} = \cos x + i \sin x$ describing the oscillatory processes of any physical nature: mechanical, acoustic, hydraulic, electromagnetic, etc.? Thus, if the component $\cos x$ in the Euler's formula describes, for example, mechanical oscillations of a pendulum, then according to the principle of physical reality of imaginary numbers they are always accompanied by a physically real process, described by the component $i \sin x$. But we neither see nor otherwise feel this unknown component $i \sin x$. The same conclusion is for oscillations of any other physical nature. So what is the process described by the component $i \sin x$?

In the cases discussed above-in the theory of electric circuits, in the special theory of relativity, in astrophysics-imaginary numbers corresponded to different physical entities. Also in case of Euler's formula the component corresponds to various physical objects, depending on sense of a component $\cos x$. That is, in each particular case (not only with respect to the Euler's formula), a special investigation is needed to answer the question about physical essence of imaginary numbers. This means that, in addition to the visible world known to us, we are surrounded by another world which is invisible and unknown to us, but actually existent.

Since it is impossible to give an unambiguous answer to the above question, let's give at least a general name for all the cases. As any numbers, both real and imaginary, serve to measure parameters of corresponding physical entities (both known and unknown), all imaginary numbers, due to their incomprehensibility and invisibility, shall be referred to as dark dimensions. Knowledge of their physical sense is a scientific task of future.

6. CONCLUSION

A number of errors were revealed in the STR using theoretically and experimentally proved principle of physical reality of imaginary numbers. In particular, the relativistic formulas of the existing version of the SRT turned out to be erroneous, and the principle of light speed non-exceedance postulated in it was disproved and the hypothesis of the Multiverse following from it has been refuted.

Use of the adjusted relativistic formulas of the STR allowed creating a verifiable hypothesis of the hidden Multiverse and Hyperverse, which has explained the phenomenon of dark matter and dark energy and also allowed us to discover the phenomenon of dark space. And existence of this dark space can be confirmed experimentally. The hypothesis of the hidden Multiverse has explained where tachyons are and why they do not violate the causality principle, as well as where antimatter is and why it does not annihilate with matter.

The article shows that neither dark matter nor dark energy, as such, exists in nature. And the terms "dark matter" and "dark energy" are just not quite specific names for other, except ours, invisible parallel universes of the hidden Multiverse, which were proposed by authors of outstanding astrophysical discoveries. It is also explained that the dark space corresponds to the other Multiverses located outside the hidden Multiverse of the Hyperverse.

The article also shows that dark matter and dark energy are a special case of the more general concept "dark dimensions", corresponding to parameters of various physical objects and processes that are measured by imaginary numbers. Therefore, the principle of physical reality of imaginary numbers induces to comprehend the sense of numerous objects, measured by such numbers.

Herewith, explanation of physical essence of numerous imaginary numbers is much more difficult problem in science than the evidence of physical reality of imaginary numbers. And therefore, the cognition of their physical essence will be the task of the science of the future.

REFERENCES

1. Oort, J.H. (1932) The Force Exerted by the Stellar System in the Direction Perpendicular to the Galactic Plane and Some Related Problems. *Bulletin of the Astronomical Institutes of the Netherlands*, **6**, 249-287.

2. Zwicky, F. (1933) Die Rotverschiebung von extragalaktischen Nebeln. *Helvetica Physica Acta*, **6**, 110-127.

3. Perlmutter, S. (2012) Nobel Lecture: Measuring the Acceleration of the Cosmic Expansion Using Supernovae. *Reviews of Modern Physics*, **84**, 1127-1149. https://doi.org/10.1103/RevModPhys.84.1127

4. Schmidt, B.P. (2012) Nobel Lecture: Accelerating Expansion of the Universe through Observations of Distant Supernovae. *Reviews of Modern Physics*, **84**, 1151-1163. https://doi.org/10.1103/RevModPhys.84.1151

5. Riess, A.G. (2012) Nobel Lecture: My Path to the Accelerating Universe. *Reviews of Modern Physics*, **84**, 1165-1175. https://doi.org/10.1103/RevModPhys.84.1165

6. Ruiz-Lapuente, P. (2010) Dark Energy: Observational and Theoretical Approaches. Cambridge University Press, Cambridge, UK.

7. Amendola, L. and Shinji, T.S. (2010) Dark Energy: Theory and Observations. Cambridge University Press, Cambridge, UK.

8. Bertone, G. (2013) Particle Dark Matter: Observations, Models and Searches. Cambridge University Press, Cambridge, UK

9. Sanders, R.H. (2014) The Dark Matter Problem: A Historical Perspective. Cambridge University Press, Cambridge, UK.

10. Weisstein, E.W. (2005) The CRC Concise Encyclopedia of Mathematics. 3rd Edition, CRS Press, Roca Raton, FL.

11. Einstein, A. (1920) Relativity: The Special and General Theory. H. Holt and Company, New York.

12. Bohm, D. (2006) The Special Theory of Relativity. Routledge, London, UK.

13. Hawking, S.W. and Penrose, R. (2010) The Nature of Space and Time. Princeton University Press, Princeton and Oxford, UK.

14. Larmor, J.J. (1897) A Dynamical Theory of the Electric and Luminiferous Medium. Part III. Relations with Material Media. *Philosophical Transactions of the Royal Society A*: *Mathematical, Physical and Engineering Sciences*, **190**, 205-300. https://doi.org/10.1098/rsta.1897.0020

15. Lorentz, H.A. (1899) Simplified Theory of Electrical and Optical Phenomena in Moving Systems. *Proceeding of the Royal Netherlands Academy of Arts and Science*, **1**, 427-442.

16. Poincaré, H. (1905) On the Dynamics of the Electron. *Comptes Rendus*, **140**, 1504-1508.

17. Einstein, A. (1905) Zur Elektrodynamik bewegter Korper. *Annalen der Physik*, **17**, 891-921.

https://doi.org/10.1002/andp.19053221004

18. Antonov, A.A. (2014) Verification of the Second Postulate of the Special Relativity Theory. *Global Journal of Science Frontier Research: A Physics & Space Science*, **14**, 51-59.

19. Adam, T., Agafonova, N., Aleksandrov, A., *et al.* (2011) Measurement of the Neutrino Velocity with the OPERA Detector in the CNGS Beam. arXiv:1109.4897v4 [hep-ex].

20. Antonello, M., Baibussinov, B., Boffelli, F., *et al.* (2012) Precision Measurement of the Neutrino Velocity with the ICARUS Detector in the CNGS Beam. arXiv: 1208.2629 [hep-ex].

21. Antonov, A.A. (2008) Physical Reality of Resonance on Complex Frequencies. *European Journal of Scientific Research*, **21**, 627-641.

22. Antonov, A.A. (2009) Resonance on Real and Complex Frequencies. *European Journal of Scientific Research*, **28**, 193-204.

23. Antonov, A.A. (2010) Solution of Algebraic Quadratic Equations Taking Into Account Transitional Processes in Oscillation Systems. *General Mathematics Notes*, **1**, 11-16.

24. Antonov, A.A. (2010) New Interpretation of Resonance. *International Journal of Pure and Applied Sciences and Technology*, **1**, 1-12.

25. Antonov, A.A. (2010) Oscillation Processes as a Tool of Physics Cognition. *American Journal of Scientific and Industrial Research*, **1**, 342-349. https://doi.org/10.5251/ajsir.2010.1.2.342.349

26. Antonov, A.A. (2013) Physical Reality of Complex Numbers. *International Journal of Management IT and Engineering*, **3**, 219-230.

27. Antonov, A.A. (2015) The Principle of the Physical Reality of Imaginary and Complex Numbers in Modern Cosmology: The Nature of Dark Matter and Dark Energy. *Journal of Russian Physical and Chemical Society*, **87**, 328-355.

28. Antonov, A.A. (2015) Physical Reality of Complex Numbers Is Proved by Research of Resonance. *General Mathematics Notes*, **31**, 34-53.

29. Antonov, A.A. (2016) Physical Reality and Nature of Imaginary, Complex and Hypercomplex Numbers. *General Mathematics Notes*, **35**, 40-63.

30. Antonov, A.A. (2017) The Physical Reality and Essence of Imaginary Numbers. *Norvegian Journal of Development of the International Science*, **6**, 50-63. http://www.njd-iscience.com

31. Antonov, A.A. (2015) Adjustment of the Special Theory of Relativity According to the Ohm's Law. *American Journal of Electrical and Electronics Engineering*, **3**, 124-129.

32. Antonov, A.A. (2015) Ohm's Law Explains Astrophysical Phenomenon of Dark Matter and Dark Energy. *Global Journal of Physics*, **2**, 145-149.

33. Antonov, A.A. (2016) Ohm's Law Is the General Law of Exact Sciences. *Ponte Academic Journal*, **72**, 131-142. https://doi.org/10.21506/j.ponte.2016.7.9

34. Antonov, A.A. (2016) Ohm's Law Refutes Current Version of the Special Theory of Relativity. *Journal of Modern Physics*, **7**, 2299-2313. https://doi.org/10.4236/jmp.2016.716198

35. Antonov, A.A. (2016) Ohm's Law Explains Phenomenon of Dark Matter and Dark Energy. *International Review of Physics*, **10**, 31-35.

36. Ohm, G.S. (1826) Bestimmung des Gesetzes, nachwelchem Metalle die Contactelektricitätleiten, nebsteinem Entwurfezur Theorie des Voltaischen Apparates und des Schweiggerschen Multiplikators. *Journal fur Chemie und Physik*, **46**, 137-166.

37. Steinmetz, C.P. (2010) Theory and Calculation of Electric Circuit. Nabu Press, Charlstone, SC.

38. Logunov, A.A. (1987) Lectures on the Relativity Theory and Gravitation. Nauka, Moscow

39. Galeczki, G. and Marquard, P. (1997) Requiem für die spezielle Relativität. Haag + Herchen Verlag, Frankfurt, Germany.

40. Arteha, S.N. (2003) Critique of the Relativity Theory Foundations. Editorial URSS, Moscow.

41. Atsyukovsky, V.A. (2003) General Etherodynamics. Energoatomizdat, Moscow.

42. Antonov, A.A. (2014) Correction of the Special Theory of Relativity: Physical Reality and Nature of Imaginary and Complex Numbers. *American Journal of Scientific and Industrial Research*, **5**, 40-52.

43. Antonov, A.A. (2011) Structure of the Multiverse. *British Journal of Science*, **2**, 51-60.

44. Antonov, A.A. (2012) Discovery of the Real Multiverse. *Encyclopedia of Russian Thought: Reports to Russian Physical Society*, **16**, 30-20.

45. Antonov, A.A. (2012) Multiverse. Time Travels. *International Journal of Pure and Applied. Scientific Technology*, **12**, 43-56.

46. Antonov, A.A. (2015) Hidden Multiverse. *International Journal of Advanced Research in Physical Science*, **2**, 25-32.

47. Deutch, D. (1998) The Fabric of Reality: The Science of Parallel Universes and Its Implications. Penguin Books, New York.

48. Greene, B. (2005) The Fabric of the Cosmos: Space, Time, and the Texture of Reality. Penguin, London, UK.

49. Kaku, M. (2006) Parallel Worlds: A Journey through Creation, Higher Dimensions, and the Future of the Cosmos. Reprint Edition, Anchor, New York.

50. Vilenkin, A. (2006) Many Worlds in One: The Search for Other Universes. Hill and Wong, New York.

51. Carr, B. (2009) Universe or Multiverse? Cambridge University Press, Cambridge, UK.

52. Gribbin, J. (2010) In Search of the Multiverse: Parallel Worlds, Hidden Dimensions, and the Ultimate Quest for the Frontiers of Reality. Wiley & Sons, Inc., Hoboken, NJ.

53. Greene, B. (2011) The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos. Vintage, New York.

54. Hawking, S. and Mlodinow, L. (2012) The Grand Design. Reprint Edition, Bantam, New York.

55. Tegmark, M. (2014) Our Mathematical Universe: My Quest for the Ultimate Nature of Reality. Vintage, New York.

56. Sommerfeld, A. (1904) Simplified Deduction of the Field and the Forces of an Electron Moving in Any Given Way. *Knkl. Acad. Wetensch*, **7**, 345-367.

57. Bilaniuk, O.-M.P., Deshpande, V.K. and Sudarshan. E.C.G. (1962) "Meta" Relativity. *American Journal of Physics*, **30**, 718-723. https://doi.org/10.1119/1.1941773

58. Feinberg, G. (1967) Possibility of Faster-Than-Light Particles. *Physical Review*, **159**, 1089-1105. https://doi.org/10.1103/PhysRev.159.1089

59. Bilaniuk, O.-M.P. and Sudarshan, E.C.G. (1969) Particles beyond the Light Barrier. *Physics Today*, **22**, 43-51. https://doi.org/10.1063/1.3035574

60. Recami, E., Fontana, F. and Garavaglia, R. (2000) About Superluminal Motions and Special Relativity: A Discussion of Some Recent Experiments, and the Solution of the Causal Paradoxe. *International Journal of Modern Physics*, **A15**, 2793-2812.

61. Tanaka, S. (1960) Theory of Matter with Superlight Velocity. *Progress of Theoretical Physics* (*Japan*), **24**, 171-200.

62. Terletskii, Y.P. (1968) Paradoxes in the Theory of Relativity. Plenum Press, New York.

63. Hill, J.M. and Cox, B.J. (2012) Einstein's Special Relativity beyond the Speed of Light. *Proceeding of the Royal Society A*, **468**, 4174-4192. https://doi.org/10.1098/rspa.2012.0340

64. Antonov, A.A. (2012) Earth, Portals, Parallel Universes. *American Journal of Scientific and Industrial Research*, **3**, 464-473. https://doi.org/10.5251/ajsir.2012.3.6.464.473

65. Antonov, A.A. (2016) Stargate of the Hidden Multiverse. *Philosophy and Cosmology*, **6**, 11-27. http://ispcjournal.org/journals/2016-16/Antonov_16.pdf

66. Chernobrov, V.A. (2000) Encyclopedia of Mysterious Places of the Earth. Publishing House "Veche", Moscow.

67. Hinshaw, G., Larson, D., Komatsu, E., *et al.* (2013) Nine Year Wilkinson Anisotropy Probe (WMAP) Observations: Cosmological Parameter Results. arXiv:1213.5226 [astro-ph/CO].

68. Adam, R., Ade, P.A.R., Aghanim, N., *et al.* (2015) Plank 2015 Results. 1. Overview of Products and Scientific Results. arXiv:1502.01582v2 [astro-ph.CO].

69. Antonov, A.A. (2015) Hidden Multiverse: Explanation of Dark Matter and Dark Energy Phenomena. *International Journal of Physics*, **3**, 84-87.

70. Antonov, A.A. (2015) Hidden Multiverse: Explanation of Dark Matter and Dark Energy Phenomena. *Cosmology*, **19**, 40-61. http://cosmology.com/AntonovMultiverse.pdf

71. Antonov, A.A. (2015) Explanation of Dark Matter and Dark Energy Phenomena. *Global Journal of Science Frontier Research*: *A Physics and Space Science*, **15**, 33-38.

72. Antonov, A.A. (2015) Principles and Structure of the Real Multiverse: Explanation of Dark Matter and Dark Energy Phenomena. *American Journal of Modern Physics*, **4**, 1-9.

73. Antonov, A.A. (2015) Why Dark Matter and Dark Energy Are Invisible? *Optics*, **4**, 43-47.

74. Antonov, A.A. (2015) The Astrophysical Phenomenon of Dark Matter and Dark Energy Proves the Existence of the Hidden Multiverse. *American Journal of Modern Physics*, **4**, 180-188.

75. Antonov, A.A. (2016) Explaining the Phenomenon of Dark Matter and Dark Energy by Existence of the Hidden Multiverse. *Frontiers of Astronomy*, *Astrophysics and Cosmology*, **2**, 1-9.

76. Antonov, A.A. (2016) Hypothesis of the Hidden Multiverse: Explains Dark Matter and Dark Energy. *Journal of Modern Physics*, **7**, 1228-1246. https://doi.org/10.4236/jmp.2016.710111

77. Antonov, A.A. (2016) What Physical World Do We Live in? *Journal of Modern Physics*, **7**, 1933-1943.

78. Antonov, A.A. (2017) Hypothesis of the Hidden Multiverse Explains the Phenomenon of Dark Matter and Dark Energy. *Applied Physics Research*, **9**, 30-41.

79. Antonov, A.A. (2017) Nature of Dark Matter and Dark Energy. *Journal of Modern Physics*, **8**, 567-582.

80. Kantor, I.L. and Solodovnikov, A.S. (1989) Hypercomplex Numbers. Springer-Verlag, Berlin.

81. Antonov, A.A. (2015) Quaternion Structure of the Hidden Multiverse: Explanation of Dark Matter and Dark Energy. *Global Journal of Science Frontier Research*: *A Physics and Space Science*, **15**, 8-15.

82. Dirac, P.A.M. (1933) Theory of Electrons and Positrons. Nobel Lecture. From Nobel Lectures, Physics 1922-1941, Elsevier Publishing Company, Amsterdam, 1965.

83. Alfvén, H. (1966) Worlds-Antiworlds: Antimatter in Cosmology. W. H. Freeman & Co., San Francisco.

84. Foot, R. (2002) Shadowlands: Quest for Mirror Matter in the Universe. Universal Publishers, Parkland, FL.

85. Frazer, G. (2004) Antimatter: The Ultimate Mirror. Cambridge University Press, Cambridge, UK.

86. Santilli, R.M. (2006) Isodual Theory of Antimatter: With Applications to Antigravity, Grand Unification and Cosmology. Springer, Dordrecht, Netherlands.

87. Alain, M. and Le Brun, V. (2012) Matter, Dark Matter, and Anti-Matter: In Search of the Hidden Universe.

Springer-Verlag, New York.

88. Antonov, A.A. (2016) Dark Matter, Dark Energy and Antimatter Are Located in the Hidden Multiverse. *Ponte Academic Journal*, **72**, 288-300. https://doi.org/10.21506/j.ponte.2016.9.22

89. Penrose, R. (2007) The Road to Reality: A Complete Guide to the Laws of the Universe. Reprint Edition, Vintage, New York.

90. Steinhardt, P.J. and Turok, N. (2007) Endless Universe: Beyond the Big Bang. Doubleday, New York.

91. Weinberg, S. (2008) Cosmology. Oxford University Press, New York.

92. Antonov, A.A. (2016) Verifiable Multiverse. *Global Journal of Science Frontier Research: A Physics and Space Science*, **16**, 4-12.

93. Antonov, A.A. (2015) Where to Look for Alien Civilisations. Cosmology. Commentaries: Stephen Hawking's Aliens. The Search for Intelligent Extraterrestrial Life. Project Breakthrough Listen.

94. Antonov, A.A. (2017) Hidden Multiverse. Extraterrestrial Super Civilizations. *Natural Science*, **9**, 43-62.