Physical Reality and Nature of Imaginary, Complex and Hypercomplex Numbers

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Abstract

Theoretical and experimental studies of oscillation processes in linear electric circuits described in the article prove physical reality of concrete imaginary numbers. Since these experimental studies are available for verification at any electronic laboratory, they are quite reliable and still not refuted, in contrast to MINOS and OPERA experiments having the similar goal. Since nature is unified and consistent, the principle of physical reality of imaginary numbers is generally scientific. Therefore, theories and hypotheses of all exact sciences such as theory of relativity, quantum mechanics, optics, radio electronics, etc. should be adjusted in accordance with this principle. It is shown how it can be done, for example, in the special theory of relativity. The article presents relativistic formulas adjusted according to the principle of physical reality of imaginary numbers. They are the basis of the conception of the hidden Multiverse which consists of mutually invisible parallel universes, coexisting in different dimensions. It is alleged that astrophysical phenomenon of dark matter and dark energy, corresponding to other invisible parallel universes, except ours, is the experimental proof of existence of the hidden Multiverse. Analysis of data from WMAP and Planck spacecrafts has showed that the hidden Multiverse has a quaternion structure.

Keywords: *Imaginary numbers, Dark matter, Dark energy, Special theory of relativity, Multiverse.*

1   Introduction

The article deals with the problem related to mathematics, astrophysics and radio electronics, as well as other physical sciences. This problem is generated by setting an unusual mathematical task specified in the article title, which cannot be solved only by mathematical means. The problem has arisen because the Nature is unified, but the science striving to cognize its laws is divided into many different scientific disciplines, which is caused by limited intellectual capacity of people. Therefore, interdisciplinary problems are not always solved optimally.

The mathematics is usually used as an auxiliary intellectual tool in exact sciences. The problem of physical reality and nature of imaginary numbers [49] discovered about five hundred years ago is that the mathematical reasoning is not less prioritized in its solution than the physical one, as shown below.

In the 20th century, instead of using experimentally based approach, traditional for exact sciences, attempts to solve this problem differently, i.e., by ignoring obtained mathematical results and postulating experimentally unconfirmed physical facts, have led physics to that of its current state, when it could not answer many of the fundamental questions: Do we live in Monoverse or Multiverse? What are dark matter and dark energy? Is there ether where tachyons and antimatter are? Etc.

For example, to avoid the necessity of explaining the essence of imaginary mass, imaginary time and other imaginary physical quantities, appearing in the relativistic formulas at superluminal speeds, the special theory of relativity (STR) [25,31] developed by Joseph Larmor [35], Nobel Prize winner Hendrik Antoon Lorentz [36], Jules Henri Poincaré [41], Nobel Prize winner Albert Einstein [24] and others was attempted to be substituted by actual development of the extended interpretation of the second postulate [5], which made the explanation unnecessary. Therefore, the original formulation of the second postulate proposed by Albert Einstein, which is referred to as the principle of light speed constancy, has been, de facto, extended by two more formulations which are actually non-identical to the original one: the principle of light speed non-exceedance and the statement on lack of physical sense in imaginary quantities.

However, the principle of light speed non-exceedance, which is often unreasonably interpreted as a consequence of the principle of light speed constancy, has not actually proved the lack of physical essence in imaginary numbers, as it contradicts common sense even at the mundane level (scientific refutation of this principle is given below). Indeed, the inability, for example, to go into the adjacent room through the wall of your house does not mean the inability to go into through the door, or the absence of the adjacent room.

Therefore, not all physicists agreed with the extended interpretation of the second postulate of the STR [5]. They conducted MINOS [3] and OPERA [2]

experiments in order to refute it by detecting superluminal neutrinos, i.e. to refute the principle of light speed non-exceedance, and thus prove physical reality of imaginary numbers (which are actually concrete, i.e. provided with references to measuring units used). Physical community refuted these experiments by ICARUS [4] experiment, which, however, didn't prove the truth of the principle of light speed non-exceedance.

Results of other experiments [6-8, 11, 12, 17], which did prove physical reality of imaginary numbers, were published almost at the same time. The principle of light speed non-exceedance was thereby refuted. And since these alternative experiments were conducted in the course of studying oscillation processes in the linear electric circuits, they could be verified in any electronic laboratory. They are so reliable that couldn't be ever refuted. And they actually haven't been.

On this occasion, Karl Raimund Popper [42], the author of the 'open society' conception, wrote, that the conflict of opinions in scientific theories is inevitable and is a prerequisite for science development. Otherwise, monopoly in science, as well as in economy, would significantly slow down the development.

2 Physical Reality of Imaginary and Complex Numbers

Now we present strictly scientific evidence of physical reality of imaginary numbers. Since Oliver Heaviside said that 'mathematics is an experimental science', let's provide description of the relevant experiments, including those set up by Nature.

2.1 The First Proof

The first proof [7, 8, 11, 17] is based on the Ohm's law, known to all educated people, which is used in other interpretation than that proposed by Ohm. Georg Simon Ohm discovered his law in 1826 [40], before the advent of electrical engineering, as a science, when there were no electrical appliances. Therefore, the formulation proposed by him related to an electric DC circuits. In 1897 Charles Proteus Steinmetz [43] developed a symbolic method which enabled application of Ohm's law for calculation of electric AC circuits. According to interpretation of Ohm's law proposed by Steinmetz, resistance of resistors in electric LCR-circuits is measured by real numbers, and reactance of inductors and capacitors is measured by heteropolar imaginary numbers. Therefore, total reactance of electric LCR-circuits is generally measured by complex numbers, and amplitude of sinusoidal electric current flowing through the electric circuits equals the ratio of applied voltage amplitude and complex impedance modulus.

The information about Ohm's law is currently contained in any textbook on the theory of electric circuits. However, none of textbooks admits that Ohm's law in

Steinmetz's interpretation proves physical reality of imaginary numbers, as well as that it is a scientific discovery. Instead, under the dominant influence of the STR textbooks claim that inductive and capacitive reactances, measured by imaginary numbers, are imaginary, i.e., physically nonexistent.

Nevertheless, this is a misconception. Should capacitive and inductive reactances be physically nonexistent, amplitude of current flowing through LCR-circuits should not have been changed at change in applied voltage frequency. However, engineers have long known that it does change. Therefore, despite its name 'imaginary', capacitive and inductive reactances are quite real. They are just as real as the resistance of resistors.

Besides, if inductive and capacitive reactances were physically nonexistent, there would be no resonance in electric LCR-circuits discovered by Galileo di Vincento Bonaiuti de'Galilei [28] in 1602. And even such sciences as radiotechnics, telecommunications, etc. also wouldn't have existed.

However, they do exist and thus prove physical reality of imaginary (and, therefore, complex) numbers and refute extended interpretation of the second postulate of the STR [5].

The activity of all electrical and radio engineers experimentally confirms the proof of the principle of physical reality of imaginary numbers.

2.2   The Second Proof

The evidence of physical reality of imaginary numbers described above is not the only possible.

The following detailed analysis of resonance, unlike approximate analysis presented in all textbooks on the theory of linear electric circuits, shows that the current resonance theory is imperfect. Resonance actually occurs at complex frequencies [12], rather than at real ones, as is commonly believed. This fact proves physical reality of complex (including imaginary) numbers. Let us see for ourselves.

First we analyze, for example, the simplest parallel oscillation circuit shown in Fig. 1, which is given in all textbooks, for the compliance with three known attributes of resonance, according to which:

- conductance (or resistance) of the electric LCR-circuit concerned becomes resistive at real resonant frequency, i.e. measured by a real number;
- conductance (or resistance) of the electric LCR-circuit concerned takes an extreme value at real resonant frequency;
- real resonant frequency equals real frequency of free oscillations.
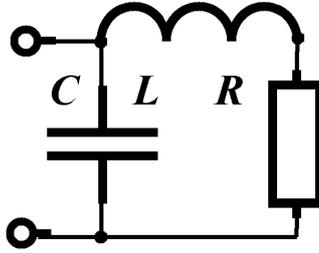
Conductance of such simplest electric circuit comprising a resistor R, a capacitor C and an inductor L is

$$Y(i\omega)=C\frac{(\dfrac{1}{LC}-\omega^2)+i\omega\dfrac{R}{L}}{\dfrac{R}{L}+i\omega}=C\frac{(\omega_0^2-\omega^2)+i\omega 2\sigma_0}{2\sigma_0+i\omega}$$

where $2\sigma_0=R/L;\ \ \omega_0=1/\sqrt{LC}\,;\ \ i=\sqrt{-1}\,.$

Therefore, the imaginary component of conductance of the electric LCR-circuit concerned is

$$ImY(i\omega)=C\frac{\omega(\omega^2-\omega_0^2+4\sigma_0^2)}{\omega^2+4\sigma_0^2}$$

Figure 1: The electric LCR-circuit concerned

Equating it to zero, we obtain the equation which solution enables to find a set of two (not one!) resonant frequencies corresponding to the first attribute of resonance

$$\left[\begin{array}{l}\omega'_{res1}=0\\[2mm]\omega''_{res1}=\sqrt{\omega_0^2-4\sigma_0^2}=\omega_0\dfrac{\sqrt{Q^2-1}}{Q}\end{array}\right.\tag{1}$$

where $Q=\dfrac{\omega_0}{2\sigma_0}=\dfrac{1}{R}\sqrt{\dfrac{L}{C}}$ is the Q factor.

Module of complex conductance of electric LCR-circuit concerned is

$$|Y(i\omega)|=C\sqrt{\frac{(\omega^2-\omega_0^2)^2+4\sigma_0^2\omega^2}{\omega^2+4\sigma_0^2}}$$

Therefore, finding the extremum of radical expression module, i.e. solving the equation

$$\frac{d}{d\omega}\left[\frac{(\omega^2 - \omega_0^2)^2 + 4\sigma_0^2}{\omega^2 + 4\sigma_0^2}\right] = \frac{2\omega[\omega^4 + 8\sigma_0^2\omega_0^2 - 16\sigma_0^4]}{(\omega^2 + 4\sigma_0^2)^2} = 0$$

we get another set of two (again, not one!) resonant frequencies corresponding to the second attribute of resonance

$$\left[\begin{array}{l} \omega'_{res2} = 0 \\ \omega''_{res2} = \sqrt{\omega_0\sqrt{\omega_0^2 + 8\sigma_0^2} - 4\sigma_0^2} = \omega_0\frac{\sqrt{Q\sqrt{Q^2 + 2} - 1}}{Q} \end{array}\right. \tag{2}$$

The result turned out to be very strange. Besides that for the same phenomenon different resonant frequencies correspond to different resonance attributes, each resonance attribute corresponds to two resonant frequencies. And the result, as shown in Fig. 2, is not mistaken. Indeed, graph of the function $Im\,Z(i\omega)$ has two points of intersection with the frequency axis ω, and graph of the function $|Z(i\omega)|$ has two extrema.

$Im\,Z(i\omega)$ ⋅ $|Z(j\omega)|$

ω ω

a *b*
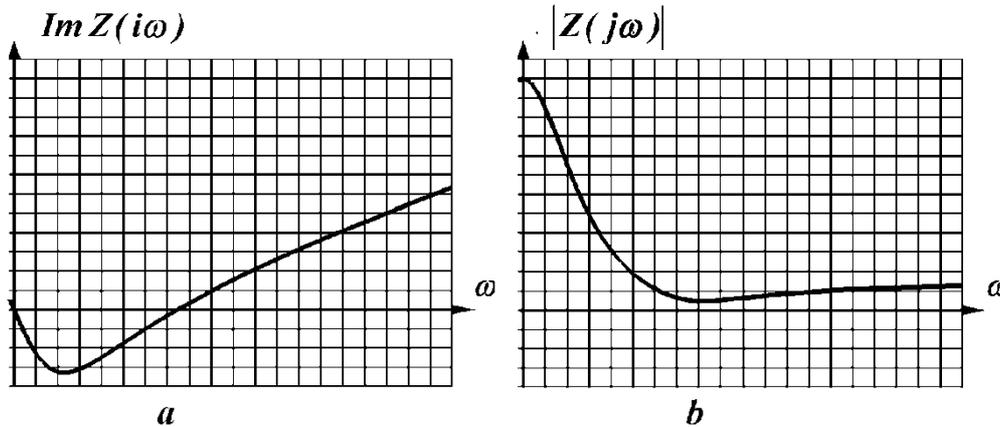
Figure 2: Graphs of functions (2) and (4)

Moreover, the exact formulas to calculate resonant frequencies for other electric LCR-circuits are different from (1) and (2).

We now verify the validity of the third resonance attribute. For this purpose, we define in a certain way real frequency of free oscillations for the electric LCR-circuit concerned

$$\omega_{free} = \sqrt{\omega_0^2 - \sigma_0^2} = \omega_0\frac{\sqrt{4Q^2 - 1}}{2Q}$$

As can be seen, it is not equal to any of the resonant frequencies corresponding to the expressions (1) and (2). The attempt to explain this fact [38] was unsuccessful. The same result is obtained by analysis of other electric LCR-circuits.

Thus, none of the resonance attributes turned out to be true. In other words, the existing interpretation of resonance is not entirely satisfactory.

However, all the above differences between resonant frequencies ω''_{res1}, ω''_{res2} and the frequency of free oscillation ω_{free} are usually quite little and do not exceed the experimental error. Therefore, the use of the approximate formula $\omega_{res} \approx 1/\sqrt{LC}$, given in all textbooks, instead of the exact formulas (1), (2) and the like, is quite justified in engineering practice.
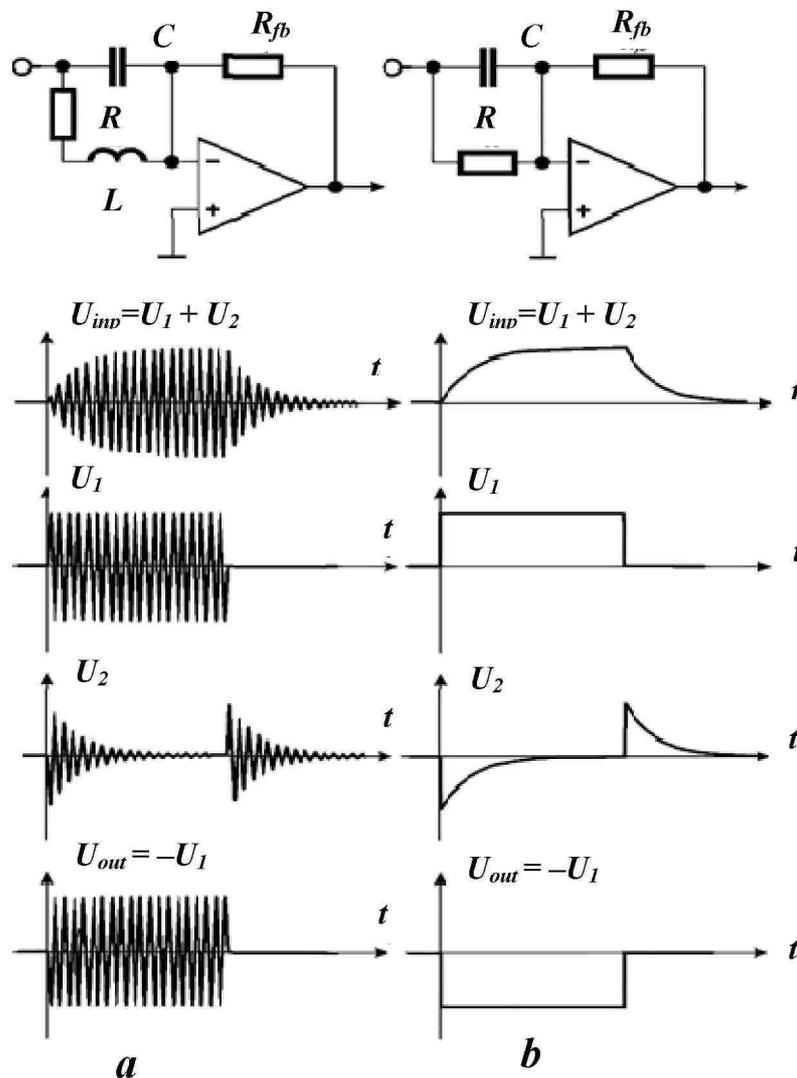
Figure 3: Examples of band-rejection filters, which use resonance at complex frequencies

Nevertheless, the difference in the results of calculating resonant frequencies according to the exact and approximate formulas does exist and requires explanation. Such explanation is given in [12]. It is based on vector diagrams at complex frequencies and ovals of Cassini and shows that resonance in electric LCR-circuits is actually possible at complex frequencies. The current interpretation of resonance only gives a description of some near-resonance processes. The truth of the theory of resonance at complex frequencies is confirmed by the fact that it fully explains all the above-mentioned disadvantages of interpretation of resonance at real frequencies.

The truth of the theory of resonance at complex frequencies is also confirmed by numerous experiments that cannot be explained by the current theory of electric circuits. One of them is described below and can be verified by any reader.

Fig. 3 shows two electric diagrams. In the input LCR-circuit of one diagram resonance occurs at complex frequencies $p_{res} = -\sigma \pm i\omega$ of exponential radio pulse U_2, whereas in the input RC-circuit of another diagram resonance occurs at complex frequency $p_{res} = -\sigma$ of exponential video pulse U_2. Therefore, only inverted rectangular radio pulse $U_{out} = -U_1$ comes to the electric diagram output from the signal $U_{inp} = U_1 + U_2$ supplied to the input of electric diagram, shown in Fig.3a, whereas exponential radio pulse U_2 does not. Similarly, only inverted rectangular video pulse $U_{out} = -U_1$ comes to the electric diagram output from the signal $U_{inp} = U_1 + U_2$ supplied to the input of electric diagram, shown in Fig.3b, whereas exponential video pulse U_2 does not. Consequently, the electric circuits discussed are band-rejection filters of complex frequencies that successfully separate signals U_1 and U_2, which cannot be separated by band-rejection filters of real frequencies.

Hence, resonance is physically real at complex frequencies rather than at real ones, and, therefore, complex frequencies and other complex (and imaginary) numbers are also physically real.

2.3   The Third Proof

The third proof is even easier than the previous two in the sense that its experimental confirmation has already been created by Nature. We only have to understand it [6]. Such a proof is represented by the existence of well-known shock oscillations, i.e. oscillations arising under impulse action: tsunami, sound of church bells and musical instruments, 'Indian summer' and even a kid's swing being pushed by parents to get a swinging motion. These phenomena could not have existed, if the extended interpretation of the second postulate of the STR were wrong. But they do exist. It means that the extended interpretation of the second postulate of the STR is refuted by Nature. Let us prove this assertion.

Oscillation processes of any physical content, including in electric LCR-circuits, are described by differential equation (usually second-order).

$$a_n \frac{d^n y}{dt^n} + a_{n-1} \frac{d^{n-1} y}{dt^{n-1}} + ... + a_o y = b_m \frac{d^m x}{dt^m} + b_{m-1} \frac{d^{m-1} x}{dt^{m-1}} + ... + b_0 x$$

where $x(t)$ is the input action (or the input signal);

$y(t)$ is the response to the action (or the output signal);

$a_n, a_{n-1}, ... a_o, b_m, b_{m-1}, ... b_0$ are constant coefficients, which are real numbers;

$n, n-1, ... 0, m, m-1, ... 0$ is the order of derivatives;

Free (or transient) component of this differential equation is found by solving the characteristic algebraic equation corresponding to it

$$a_2 p^2 + a_1 p + a_0 = 0 \tag{3}$$

where $p = -\sigma \pm j\omega$ is referred to as complex frequency with regard to oscillation transient. The oscillation transient is thereby described by the function

$$y_{free} = e^{-\sigma}(A \sin \omega t + B \cos \omega t) \tag{4}$$

where A and B are integration constants found from the initial conditions.

As can be seen, oscillation transient (4) corresponds to the solution of the characteristic algebraic equation (3) only in the form of a pair of complex conjugate numbers $p = -\sigma \pm j\omega$. For this reason, characteristic algebraic equations are solved only on the set of complex numbers.

Otherwise, if characteristic algebraic equations (3) were solved on the set of real numbers, the solutions in the form of $p = -\sigma \pm i\omega$ could not be obtained in any combination of factors a_2, a_1, a_0. And regarding this fact we would inevitably have to conclude that oscillation transients should not ever exist.

However, they do exist! These are the above mentioned tsunami, kid's swing and other oscillation transients.

Therefore, we have to recognize solutions of algebraic equations (not only characteristic) on the set of complex numbers, and, consequently, complex (including imaginary) numbers themselves as physically existent.

3 Physical Nature of Imaginary and Complex Numbers

Confirmation of physical reality of imaginary and complex numbers is not enough to fully understand what they are like. It is also desirable to explain their nature. In other words, we have to answer the question of how they can be seen, touched, heard or otherwise felt.

Unfortunately, it is still impossible, because people do not have such senses (though it may be possible that other living beings such as, for example, cats have such capabilities). This situation is not unique. People also cannot see, touch, hear or otherwise feel many other physical entities corresponding to real numbers. They cannot see ultraviolet light and dark matter, hear infrared and ultra sounds, touch molecules and elementary particles, feel magnetic field and X-ray radiation. However, people have verified their existence using appropriate equipment, which converts initial data into information that is perceivable by our senses. We can, therefore, assume that in the future people will create the equipment for detecting many more unknown physical entities corresponding to imaginary numbers, just as they have already created radio-electronic equipment for measuring imaginary reactance and conductance mentioned above.

3.1 Adjustment of the STR: The Structure of the Multiverse

Nature is unified and consistent. Therefore, Science, striving to cognize It, should also be internally consistent. All scientific disciplines with their theories and hypotheses should be mutually consistent in science. Otherwise, at least one of inconsistent theories would be incorrect t (as, for example, quantum mechanics and theory of relativity in physics).

Consequently, the principle of physical reality of imaginary and complex numbers proved in the theory of electric circuits is generally scientific. All exact scientific theories, such as quantum mechanics, theory of relativity, optics, radioelectronics and others, should be adjusted in accordance with this principle.

Let us show an example of how it can be done in the STR [7]. Apparently, we should first of all explain what physical sense relativistic formulas at superluminal speeds have, when $v > c$. For example, the Lorentz-Einstein formula

$$m = \frac{m_0}{\sqrt{1 - (v/c)^2}} \tag{5}$$

Where

m_0 is the rest mass of a moving entity (for example, of elementary particle);

m is the relativistic mass of a moving entity;

v is the velocity of a physical entity;

c is the speed of light.

As can be seen, relativistic mass m in this formula at sub-light speeds $v > c$ is a real value, whereas at superluminal speeds $v > c$ it becomes an imaginary value. As the STR has failed to explain what imaginary mass (as well as imaginary time and other imaginary physical quantities) is like, the principle of light speed non-exceedance has actually been postulated therein [5]. However, physical reality of imaginary numbers, proved above in the most indisputable way, refutes the principle of light speed non-exceedance. Thus, the meaning of imaginary physical values actually existing in the STR still needs to be explained.

The explanation is as follows. When $v > c$, physical entities, e.g. tachyons [26, 45], with imaginary mass m, which cannot be registered in our universe, but, nevertheless, are physically existent, are at some another place. This place should for clarity be referred to as a tachyon universe. Our universe should be called 'tardyon' (from the name of elementary particles moving at sub-light speeds). Hence, it can be concluded that there is a Multiverse [13], which contains at least two universes: tardyon and tachyon. However, since tachyon universe corresponds to the condition $v > c$, it is behind the event horizon and therefore invisible to us. For this reason, Multiverse is also unobservable to us and should be referred to as hidden [9, 13, 16, 19].

As tachyon universe is an inertial reference system, it has the same physical, chemical, and other laws of nature that operate in our universe. It is easy to see that the Lorentz-Einstein equation (5) does not meet this condition. Therefore, it can be converted into the formula (6)

$$m = \frac{exp(iq\frac{\pi}{2})m_0}{\sqrt{1-(\frac{v}{c}-q)^2}} = \frac{exp(iq\frac{\pi}{2})m_0}{\sqrt{1-(\frac{w}{c})^2}} \tag{6}$$

where $q = \lfloor \frac{v}{c} \rfloor$ is the discreet 'floor' function of argument $\frac{v}{c}$;
$w = v - qc$ is the local velocity for each universe, which can take values only in the range $0 \leq w < 0$;
v is the velocity measured from our tardyon universe, which, therefore, can be called a tardyon velocity.
c is the speed of light.

Other relativistic formulas can be adjusted in a similar manner.

As follows from the formula (6) such a Multiverse might have more than two universes, i.e. in addition to tardyon and tachyon universes corresponding to $q = 0$ and $q = 1$ the hidden Multiverse can contain a tardyon antiverse corresponding to $q = 2$, tachyon antiverse corresponding to $q = 3$, another

tardyon universe corresponding to $q = 4$ and another tachyon universe corresponding to $q = 5$ etc.

Besides, annihilation of universes and antiverses, both tardyon and tachyon, is fully prevented due to the specified alternation of universes and antiverses.

An example of such a closed structure of the hidden Multiverse for the total number of universes equal to twenty-four is shown in Fig. 4. As can be seen, this structure is somewhat reminiscent of a DNA molecule. In such a structure our tardyon universe in the form of a screw collar, which is both conditional beginning and end of reference, is shown twice and denoted by dashed line.
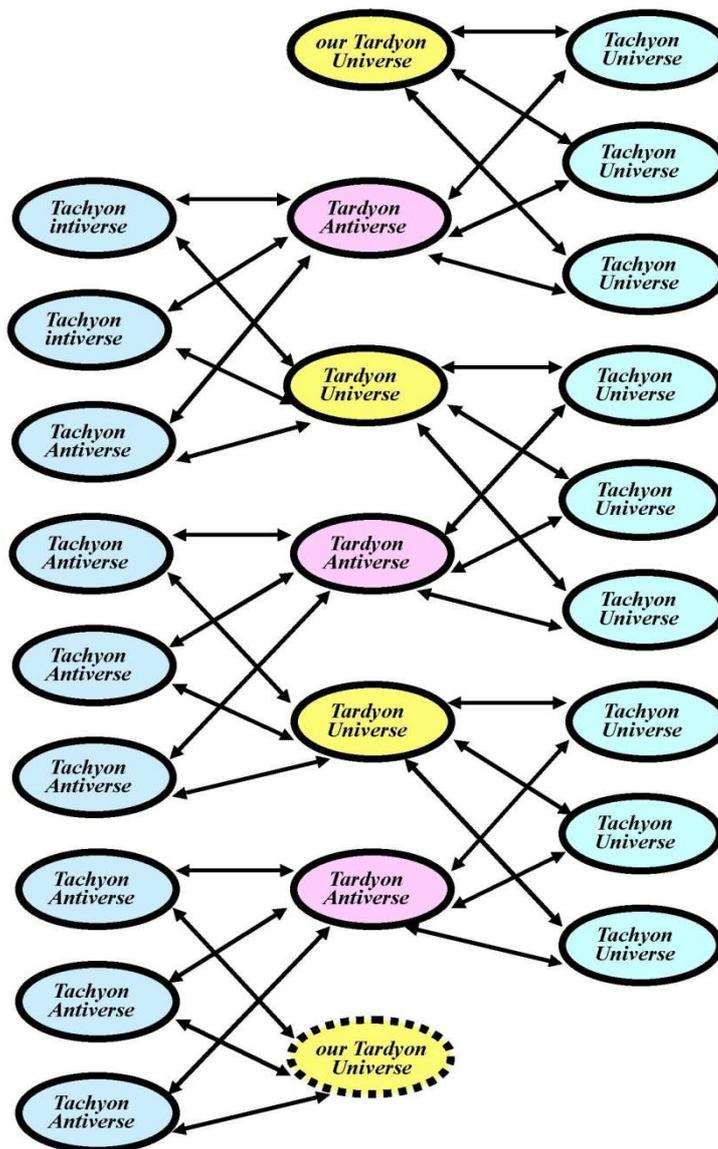
Figure 4: Possible structure of the hidden Multiverse, corresponding to the principle of physical reality of complex numbers

Universes in this structure are called parallel, because despite its infinity, they never intersect. They drift in multidimensional space under the action of still unknown mechanism of automatic adjustment of their spatial position. Parallel universes sometimes touch each other in some spots and even slightly penetrate into each other. Then, these spots, referred to as portals or star gates, denoted by bidirectional arrows in Fig. 4, allows elementary particles and their living inhabitants (but not planets and stars) to transit from one universe to another (or, in other words, from one dimension to another) without overcoming light speed barrier. Due to existence of portals, mass-energy of parallel universes in the hidden Multiverse is averaged to a certain extent.
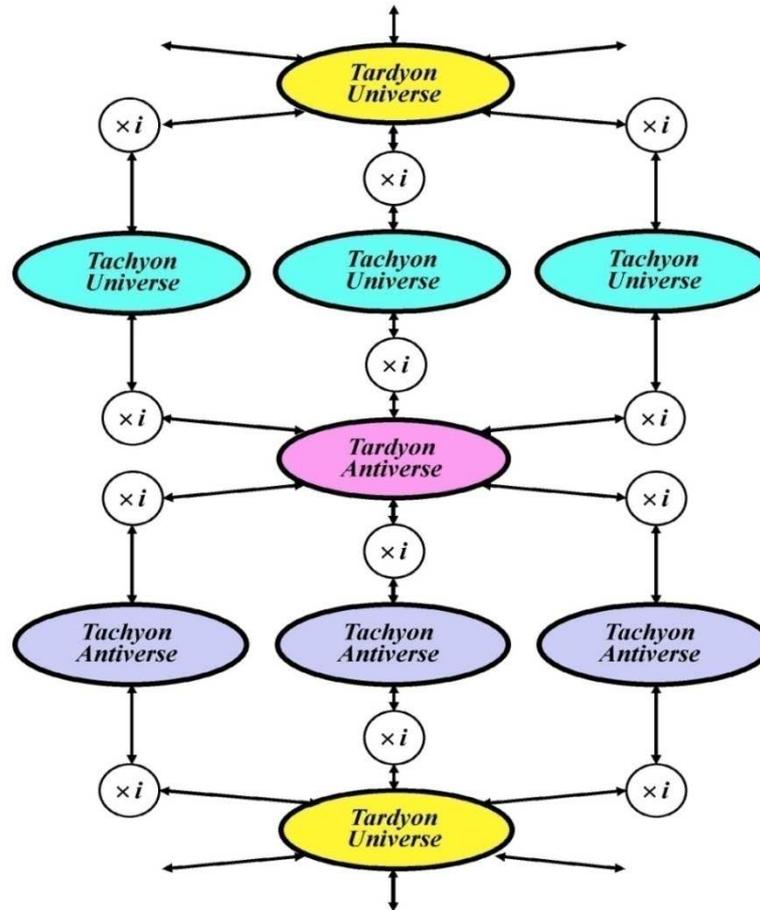
Figure 5: The algorithm of transformation of physical entities in the hidden Multiverse, the structure of which is shown in Fig. 4

Fig. 5 shows that in portals, according to the formula (6), real physical entities measured by real numbers are transformed into equally real physical entities measured by imaginary numbers, and then into real physical entities measured by negative real numbers (for example, negative time, negative mass) and so on, with changing parameter q in the function $exp(iq\frac{\pi}{2})$. However, we have yet to understand the nature of these transformations which enable transitions from one dimension to another.

3.2   Explanation of Dark Matter and Dark Energy

The hypothesis of the hidden Multiverse described above, unlike other hypotheses of Multiverse, some of which are discussed in [21-23, 29, 30, 34, 37, 43, 46-48], is confirmed experimentally by existence of dark matter discovered by Jan Hendrik Oort and Fritz Zwikky in 1932-33 and dark energy discovered by Nobel Prize winners Saul Perlmutter, Brian P. Schmidt and Adam G. Riess in 1998-99 [27, 39]. Indeed, what could be more natural than the assertion that invisible dark matter and dark energy are invisible parallel universes of the hidden Multiverse [9-11, 14-16, 18-20]?

However, until now it has not been ever asserted at least for two reasons:

- Explanation of invisibility of parallel universes within the conception of the hidden Multiverse using the principle of physical reality of imaginary numbers required that this principle was first proved and thus refuted the principle of light speed non-exceedance in the STR, though this was not done;
- Explanation of existence of invisible parallel universes by some other reasons turned out to be no easier than explanation of invisibility of dark matter and dark energy within the conception of Monoverse corresponding to the current version of the STR.

If we take into account the 'Occam's blade' criterion, explanation of the phenomenon of dark matter and dark energy by existence of the hidden Multiverse should be recognized as the most appropriate, as it is extremely simple and provides reasonable answers to the questions concerned:

- Invisible dark matter corresponds to other invisible parallel universes of the hidden Multiverse adjacent to our universe;
- Invisible dark energy corresponds to other invisible parallel universes of the hidden Multiverse, shielded from our universe by dark matter;
- Inability to determine chemical composition of dark matter and dark energy is explained by the fact that the object of study, i.e., physical content of 'dark' universes, is not in our universe in which there are analysis tools belonging to people.

Besides, data obtained from WMAP [32] and Planck [1] spacecrafts suggest that:

- According to Planck calculations the hidden Multiverse contains $100\,\%/4{,}9\,\% \approx 20{,}41$ parallel universes (according to earlier and less accurate WMAP calculations $100\,\%/4{,}6\,\% \approx 21{,}74$), that is, most likely, twenty-one parallel universes;

- According to Planck calculations $26{,}8\%/4{,}9\% \approx 5{,}47$ universes are adjacent to our universe (according to less accurate WMAP calculations $22{,}4\%/4{,}6\% \approx 4{,}87$), that is, most likely, six parallel universes.

3.3   Multidimensional Space of the Hidden Multiverse

Thus, it would seem that there is a good conformity of calculation data with block diagram of the hidden Multiverse, shown in Fig. 3. Unfortunately, it is not.

In fact, the hidden Multiverse cannot have a block diagram, shown in Fig. 3, in which tardyon universes are, according to the WMAP and Planck data, adjacent to six tachyon universes and antiverses. The point is parallel universes of the hidden Multiverse are in different dimensions, which in the formula (6) correspond to different values of parameter q. And obviously, there cannot be several parallel universes at the same place, i.e. in the same dimension. So, one and the same value of parameter q cannot correspond to several universes. Therefore, according to the formula (6) the hidden Multiverse corresponding to the principle of physical reality of complex numbers can only have a helical structure, in which each universe has only two adjacent universes, that is not consistent with mathematical data of WMAP and Planck.

The above reasoning does not mean that the principle of physical reality of imaginary numbers is not applicable in the STR. In fact, only a particular case of its use in the form of complex numbers turned out to be inapplicable. However, as shown below, it is applicable in the STR in more general case, i.e. in the form of hypercomplex numbers.

4   Physical Reality and Nature of Hypercomplex Numbers

The results of calculations in p. 3.2 generate two obvious questions.

Firstly, why does the hidden Multiverse contain twenty-one universes instead, for example, twenty-four (as in Fig. 4), for which its structure would be closed? No one can currently give a convincing answer for this question. Although, it is permissible to assume that parallel universes in the hidden Multiverse can have markedly different mass-energy and, therefore, their number can actually be twenty-four. It can also be assumed that in the open-loop structure edges of the hidden Multiverse are connected to other Multiverses that are not recorded by earth tools.

Secondly, why are there six adjacent universes? It is also difficult to answer this question conclusively. But we can assume that (as explained below) tardyon universes have exactly six adjacent parallel universes by virtue of the fact that the structure of the hidden Multiverse is quaternion. Three tardyon universes and

three tachyon antiverses corresponding to triples of different imaginary units i_1, i_2, i_3 together constitute six adjacent parallel universes.

4.1 Physical Reality of Hypercomplex Numbers

In relation to the task of determining the structure of the hidden Multiverse from hypercomplex numbers, quaternions [33] $\sigma + i_1 \omega_1 + i_2 \omega_2 + i_3 \omega_3$ are of greatest interest, because they contain three imaginary units i_1, i_2, i_3. And these three imaginary units are connected by the following relations

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

$$i_1 i_2 i_3 = i_2 i_3 i_1 = i_3 i_1 i_2 = -1 \tag{7b}$$

$$i_1 i_3 i_2 = i_2 i_1 i_3 = i_3 i_2 i_1 = 1 \tag{7c}$$

where products of imaginary units i_1, i_2, i_3 (7b) and (7c) are not commutative.

Physical reality of quaternions can be proved by the study of oscillation processes in resonance chambers, similar to the study of oscillation processes in linear electric circuits, described above. However, the following is more interesting proof of this assertion, derived from the analysis of the most probable structure of the hidden Multiverse.

4.2 Physical Reality of Hypercomplex Numbers

With regard to quaternion structure of the hidden Multiverse, Lorentz-Einstein formula should be once more adjusted by its conversion into the formula

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

$$= \frac{m_0 \exp(q i_1 \pi/2) \exp(r i_2 \pi/2) \exp(s i_3 \pi/2)}{\sqrt{1 - (w/c)^2}} \tag{8}$$

where q is the total number of parallel universes, penetration into which was made through portals, corresponding to the imaginary unit i_1, with increasing distance from our tardyon universe;

r is the total number of parallel universes, penetration into which was made through portals, corresponding to the imaginary unit i_2, with increasing distance from our tardyon universe;

s is the total number of parallel universes, penetration into which was made through portals, corresponding to the imaginary unit i_3, with increasing distance from our tardyon universe;

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

c is the speed of light;

$w = v - (q + r + s)c$ is the local velocity for corresponding universe, which can take values only in the range $0 \leq w < 0$.
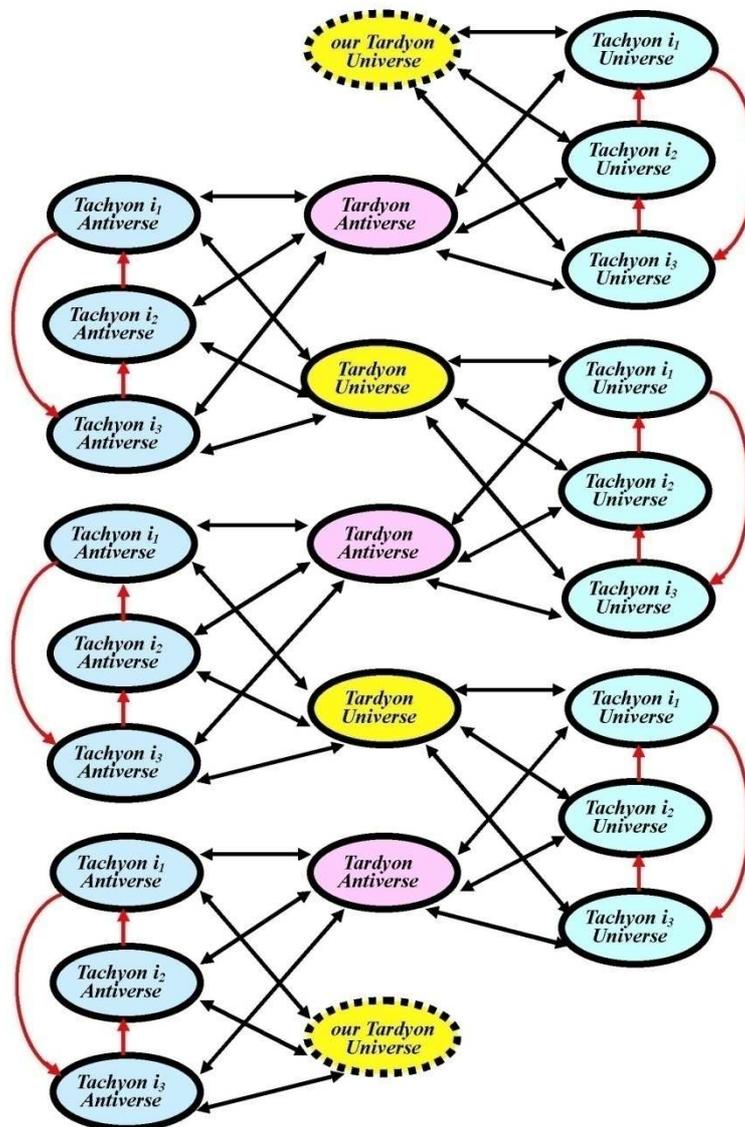
Figure 6: Possible structure of the hidden Multiverse, corresponding to the hypothesis of physical reality of quaternions

Other relativistic formulas of the STR can be adjusted in a similar manner. As can be seen in the formulas (7), there are three parameters *q, r* and *s* when using quaternions, instead of a single parameter *q* when using complex numbers, which actually provides a solution to the problem of explaining the existence of six adjacent universes.

Fig. 6 shows the quaternion structure of the hidden Multiverse (very similar to the structure shown in Fig. 4) containing twenty-four parallel universes. It corresponds to data obtained from WMAP and Planck spacecrafts. Fig. 7 presents the algorithm of its functioning. As can be seen, quaternion structure of the hidden Multiverse is distinguished from the structure of the Multiverse corresponding to the principle of physical reality of complex numbers, shown in Fig. 4, only by availability of additional unidirectional portals (in Fig. 6, 7 they are denoted by red unidirectional arrows). As these portals are unidirectional, they, unlike bidirectional ones, don't allow returning back to a home universe.
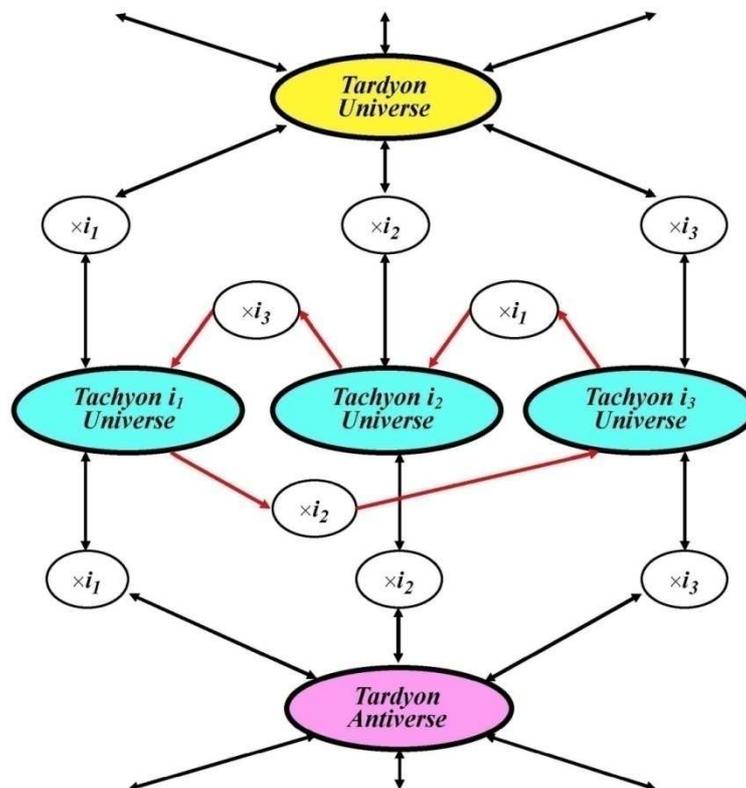
Figure 7: The algorithm of transformation of physical entities in the multidimensional space of the hidden Multiverse with quaternion structure

The appearance of unidirectional portals in the quaternion structure of the hidden Multiverse is caused by the fact that, apart from condition (7a) similar to the condition $i^2 = -1$ for complex numbers, imaginary units i_1, i_2, i_3 in quaternions are interconnected by additional relations (7b) and (7c).

In Fig. 6, 7 portals marked by black bidirectional arrows implement the same transformations of physical entities as in Fig. 5. Additional portals, shown in Fig. 6, 7 by red unidirectional arrows, implement transformations of physical entities corresponding to the following relations from (7b):

- $i_1 i_2 = i_3$, which is implemented by a portal i_2 located between tachyon universes corresponding to the imaginary units i_1 and i_3;

- $i_3 i_1 = i_2$, which is implemented by a portal i_1 located between tachyon universes corresponding to the imaginary units i_3 and i_2;

- $i_2 i_3 = i_1$, which is implemented by a portal i_3 located between tachyon universes corresponding to the imaginary units i_2 and i_1.

The same additional portals, shown in Fig. 6, 7 by unidirectional arrows, implement transformations of physical entities, corresponding also to the following relations from (7c):

- $i_1(-i_3) = i_2$, which is equivalent to the relation $i_2 i_3 = i_1$ and therefore also implemented by a portal i_3 located between tachyon universes corresponding to the imaginary units i_2 and i_1;

- $i_3(-i_2) = i_1$, which is equivalent to the relation $i_1 i_2 = i_3$ and therefore also implemented by a portal i_2 located between tachyon universes corresponding to the imaginary units i_1 and i_3;

- $i_2(-i_1) = i_3$, which is equivalent to the relation $i_3 i_1 = i_2$ and therefore also implemented by a portal i_1 located between tachyon universes corresponding to the imaginary units i_3 and i_2.

According to the formula (8), quaternion structure of the hidden Multiverse containing twenty-one parallel universes, which is, presumably, more consistent with WMAP and Planck data, is shown in Fig. 8. This structure is, apparently, not completely closed, i.e. it has edges. These edges connect our hidden Multiverse with other hidden Multiverses (or connect it with one and the same hidden Multiverse several times). Together they form Supermultiverse. These other hidden Multiverses are unobservable from the Earth not only by electromagnetic but also by gravitational manifestations. Therefore, they have not been registered by WMAP and Planck spacecrafts.

Thus, existence of the quaternion structure of the hidden Multiverse, corresponding to WMAP and Planck spacecraft data, proves also physical reality of quaternions.
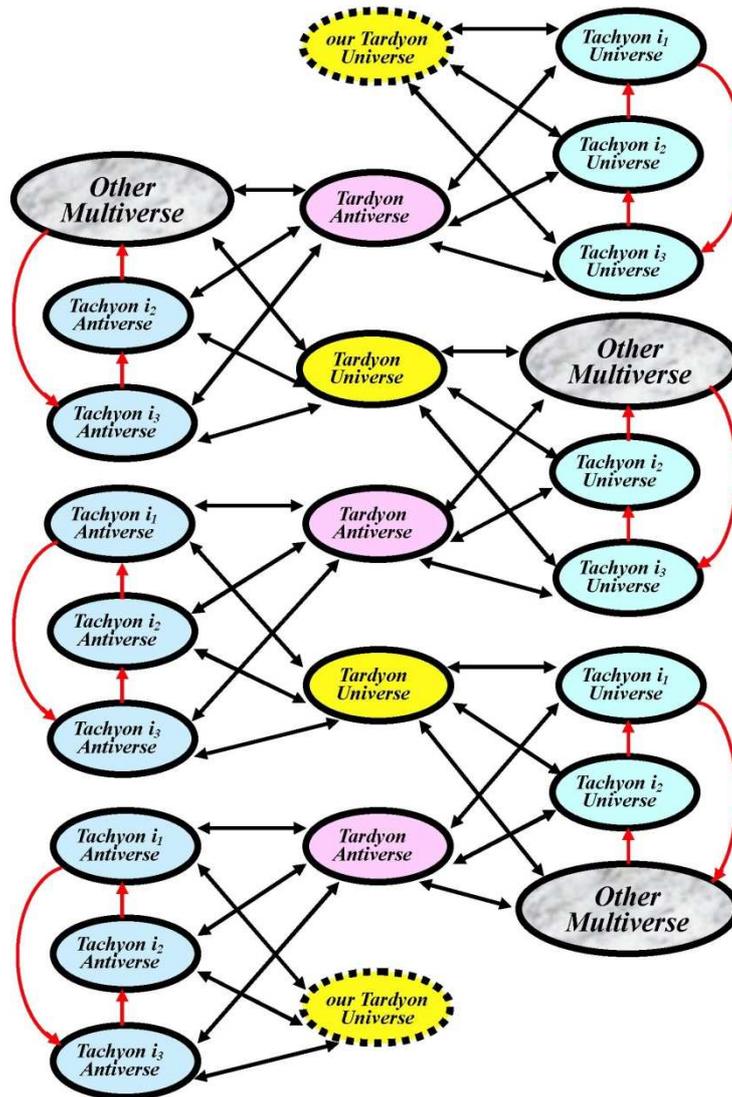
Figure 8: The most likely structure hidden Multiverse corresponding hypothesis about the physical reality of quaternions

Each universe in such a structure of the hidden multiverse corresponds to its integer q, r, s. In Fig. 9 coordinates x, y, z symbolically indicate an internal three-dimensional space of separate universes, and coordinates q, r, s show space of extra dimensions of universes within the hidden multiverse. Consequently, we live in six-dimensional space (regardless of time), rather than in four-dimensional, as previously assumed.

Finally, as shown in Fig. 6 and 8, the structure of the hidden Multiverse corresponding to the principle of physical reality of quaternions, contains four matter-antimatter pairs corresponding to tardyon universes and antiverses, as well
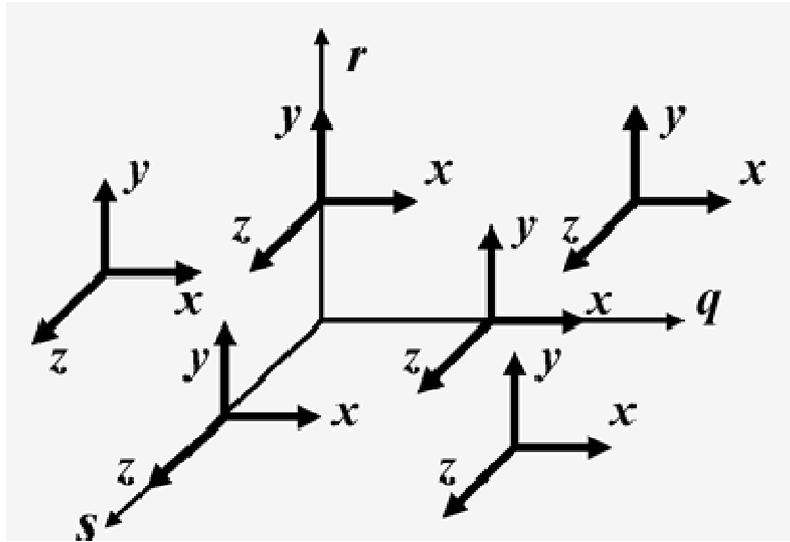
Figure 9: Six-dimensional space of the hidden multiverse

as to three different types of tachyon universes and antiverses. Their annihilation is excluded in all of these structures because of certain alternation in the space of different parallel universes. In this regard, it is notable that there is no place for antimatter, which theoretically must exist, in Monoverse, corresponding to the current version of the STR, due to lack of protection from its mutual annihilation with matter. This fact can be considered as yet another proof of groundlessness of the current generally accepted version of the STR.

5   Conclusion

Physical reality of concrete imaginary, complex and hypercomplex numbers has been proved in the most indisputable way. Therefore, all exact sciences should be adjusted in accordance with the principle of physical reality of imaginary numbers.

The use of this principle in the STR allowed, on the basis of its revised version, developing the conception of the hidden Multiverse, which has explained the phenomenon of dark matter and dark energy.

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