The structured vacuum theory

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Abstract

The novel physical model sheds light on the matter spatiotemporal organization of the universe. It makes an attempt to create a basis for revealing the hidden mechanisms underlying all the laws of modern physics. In addition to explaining mechanisms of well-known phenomena, the model claims to explain the origin of such basic phenomena as inertial and gravitational masses, electrical charge, and magnetic moment. The model may be briefly summarized in the following conclusions:

- the energy of the universe is stored in a perpetual motion of superfluid substance. The substance flows are shaped as double-helical streamlines and vortices;
- structure of each stable physical object supports resonant oscillation in which are involved equal amounts of kinetic and potential energies. The energy content of any physical object or physical event can be represented by Fourier spectral decomposition of inner resonant oscillations;
- at any frequency (or wavelength) component of this Fourier expansion, the physical object tends to perform the steepest descent of its free energy content, namely, to balance the kinetic and potential energies of its inner oscillations. The free energy descent appears to be equivalent to the maximization of the ratio between the reactive power of inner oscillations and the object's active losses. We shall name this ratio as a quality factor. At locations where the available energy density of the superfluid flows is sufficiently large, the optimization process leads to the generation of a *continuous* lattice composed of identical contours involved in coherent oscillation. The lattice occupies the continuous 3D areas of the universe. The lattice generation may occur at any frequency/wavelength of the spectral continuum. The lattices are similar structures belonging to a variety of spatial scales.
- Each elementary cell of each continuous lattice and at any spatial scale has a hexagonal shape. The sides of the hexagons are comprised of straight double-helical filament streams, while the hexagon corners (the lattice nodes) are occupied by double vortices. The double-helices are composed of clockwise and counterclockwise vortices forming double-helical flows curled to a torus. Vortices are multiple-frequency resonant structures, and they energetically couple coherent lattices occupying a continuum of spatial scales.
- At any spatial scale, the lattice of double-helical flows and vortices supports two types of self-oscillations: anti-symmetric (identified with gravitational energy modality), and symmetrical (electromagnetic energy modality).
- There is a discrete plurality of lattices in which full exchange occurs between the energy of gravitational and the energy of electromagnetic modalities. Such exchange may take place only if the gravitational modality belongs to the lattice of a much smaller spatial scale. Such special lattices are efficient energy attractors. The vacuum lattice is the last in the chain of such special lattices. Formation of the vacuum lattice exhausts the density of free universe energy in a given location. The perimeter of hexagon cells of this lattice equals Planck length, and all cells are involved in coherent inner oscillations at the Planck frequency;
- If the available energy density is insufficient for the generation of continuous lattice, the remnant after the vacuum formation energy generates massive particles, the discrete isolated physical objects with closed-contour structures supporting self-oscillations at the object's resonance De Broglie frequency.
- The stability of each physical object may be characterized by its quality factor. The most important for our physical reality object is the Planck-scale vacuum lattice, the last in the lattice continuum, exhausting the universe's energy. The vacuum lattice is the most stable among detectable objects. The lattice provides mechanisms for all observable to us energy transformations and gives birth to all elementary particles in the form of their own phononic excitations. The energy remnant after the vacuum lattice generation is stored within the massive particles and is redistributed to long ranges mainly by means of zero-mass particles, like photons and

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their analogs carrying gravitational energy. Massive particles and zero-mass particles are phononic modulations of the same Planck-frequency carrier. Massive particles are phononic excitations generated by amplitude modulation of the Planck frequency oscillations in elementary cells of the vacuum lattice. Photons and their gravitational analogs are zero-mass phononic excitations generated by phase modulation of the vacuum lattice oscillations at the Planck frequency.

- The matter organization within the frequency band below the Planck frequency is fractal. The fractal is a hierarchy of nested structures of different spatial scales. Energy exchange between the *kinetic* energy modality of one scale with the *potential* energy of the other scale creates a phenomenon of *spatial resonance*. Structures generated by spatial resonance are the most stable ones, from quarks and up to objects of cosmic scales. The entire universe appears to be such a fractal. Each spatial resonance within the fractal serves as an energy attractor and is relatively densely populated by a variety of stable physical objects of similar spatial frequency scales. Zones of spatial resonance are separated by wide not populated spectral gaps. Each spatial resonance is due to the energy exchange of kinetic/potential electromagnetic energy and an equal amount of potential/kinetic gravitational energy. The energy exchange is between electromagnetic (symmetrical mode) oscillations and gravitational (anti-symmetric) oscillations of much higher frequency. Ratios of gravity-to-electromagnetic oscillation frequencies involved in the same spatial resonance are a universal constant and take the same value for all spatial scales. Hence the De Broglie frequencies of the nested spatial resonances constitute geometrical progression.

The model exposition is culminated by a short description of quarks agglomeration to proton and neutron forming massive structures of enhanced stability. It is also shown how free (not compensated) quark's energy of inert and gravity masses, electric charge and magnetic moment generate the phenomenon of bonded electrons. The electrically neutral atomic structure is presented as a plurality of vortex structures produced by several spatial resonances. Each spatial resonator is a conically shaped vortex and exists due to energy exchange between a single nuclide and two associated with its bonded electrons belonging to the same stationary orbit.

Keywords: Structured matter, Vacuum lattice, Elementary particles, Quantum physics

Content

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1. Introduction

This theory makes an attempt to overcome two fundamental methodological problems of modern physics, namely: (1) adherence mostly to the phenomenological methodology. Traditionally, the physical theory is culminated by the development of mathematical equations and formulas correctly describing the phenomenon but not claiming to explain its internal mechanisms; (2) the existence of a large set of axioms underlying physical theories. Numerous theories are currently not unified by a single super-theory explaining all of the phenomena. In the past, the phenomenological approach played a positive role in the development of human knowledge but has shown some of its shortcomings in modern physics. This happened at a time when direct measurements of objects with sizes smaller than 10^{-9}m became technically impossible, as, say, in the case of quantum mechanical phenomena. In the absence of direct observations for verification of physical concepts, other criteria were required to prove the validity of the physics models. The results of experiments still continued to serve as a method for indirect testing of the correctness of theories, however, the results interpretation became more and more ambiguous. As a result, an attempt was made to summarize the experimental results in the form of principles, rules, and laws. Unfortunately, a large number of such postulated principles, rules, and laws have accumulated, which led to understandable dissatisfaction. The era of the search for one unified theory has come, which could replace many disparate rules and laws. Recently, several attempts have been made to create a “theory of everything”, which would become a common denominator unifying all earlier developed phenomenological theories, principles, and rules. Obviously, to create such a theory, it will be necessary to introduce a single initial axiom that does not follow exclusively from phenomenological observations but is based on a single universal principle. As such an initial axiom, the novel theory presented in this paper assumes that all energy of the entire universe is invested in the motion of hypothetical inert, inviscid, and not compressible superfluid substances. The energy conservation principle, the universality of which has repeatedly been verified in many branches of modern physical science, was adopted as the fundamental principle orchestrating the flows of this primordial substance. In the course of the novel model development, the interrelationship of the two posed above problems of modern physics becomes clearly exposed. In addition, a clear understanding of hidden mechanisms of all known to us physical phenomena allows the minimization of axiomatic basis and enables us to take a glimpse at what is beyond the laws of modern physics. The new model proposed in this theory enables a deeper understanding of seemingly disparate physical phenomena, which entailed an extremely large amount of material that we are trying to cover in this primary article. Initially conceived as a relatively small part of an overview report, this article has been consequently supplemented with a few additional paragraphs. We have seen it as our task to reflect only the main ideological part of the model, without giving it a rigorous analytical form. The reader will surely turn his attention to the fact that many ideas are taught in verbal form, without even citing elementary equations. In this, we see the main drawback of this work, which makes it necessary to develop this project into its next stage when most of the ideas will finally be clothed in the form of mathematical equations and their solutions. The presented theory is at the initial stage of its development. This text was prepared as a brief introduction to the sphere of ideas on the basis of which it is proposed to develop this new paradigm of our physical reality. The presentation does not claim to be complete and is limited mainly by qualitative considerations. The unification of the phenomena of gravity and electromagnetism and the demonstration of their common origins is the central point of the entire exposition.

2. On the primacy of the energy conservation principle

Since the 17th century, the energy conservation principle has been a cornerstone underlying modern physics. However, additional fundamental principles emerged, on the basis of which it became possible

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to successfully formulate and solve physical problems. In particular, the optimization principles of Lagrange and Hamilton appeared to be universal and sufficient to be the solid basis of actually any branch of modern physics. Hence, the question arises of which of the principles is primary: energy conservation or variational?

The correct answer to this question is of fundamental importance for understanding the universe as a primary physical object, in particular, if we assume that the universe's behavior is guided by considerations of some supreme order. Based on these positions, we may interpret so triumphal success of variational principles in physics as evidence of the universe dynamics obedience to some supreme principle. In this case, proper selection of the system optimization goal has a greater significance than a mere successful methodological or computational technique, and the correct formulation of the optimization goal can reveal to us the essence of these higher-order considerations. In other words, it is possible that variational methods have an ontological basis, and do not belong to the category of epistemology.

At this point, we propose to find out what are the consequences of recognizing the principle of energy conservation as the supreme one. As it will soon become clear, such an apparently simple step enables us to make very important conclusions regarding the energetic structure of physical systems, including the structure of the entire universe.

It is known that the energy conservation principle can be formally obtained from the Hamilton or Lagrange variational principles by means of mathematical transformations. However, the authors of [1] ask the following questions: "*Since the principle of energy conservation has been so widely accepted, and it is natural to ruminate that, rather than using Hamilton's variational principle, why don't we start from the first principle of physics, the principle of energy conservation to construct the basic principles of analytical mechanics? Is that possible to take the principle of energy conservation as an axiom to reconstruct the whole mechanics?*" In this paper, the authors give a positive answer to both questions, deriving the principles of Hamilton and Lagrange from the energy conservation law. The [1] shows the way how to incorporate Lagrangian L or Hamiltonian H of a system into the energy conservation equation using Legendre's transformation for the Hamiltonian definition through Lagrangian.

The conclusion that the principle of energy conservation may turn out to be the most primary in the entire hierarchy of physical principles becomes especially important when developing a model for the universe's structure. It is sufficient to recognize that the universe is just one of the physical objects, despite its special role. In addition, it is natural to assume that every physical object, by means of its structure, dynamics, and to the best of its humble capabilities, tries to contribute to the achievement of this ultimate energy conservation goal at the universal level.

Adopting as an axiom that the energy conservation principle is the supreme one, we may come to the conclusion that the primary goal of any physical process is energy accumulation and its efficient conservation. In other words, the stable physical object behaves like a kind of energy vampire. Then the appeal to variational methods in the physical systems analysis is a kind of recognition of the fact that any physical system is in the permanent process of optimizing some primary goal parameter. Moreover, the recognition of the energy conservation law primacy means that the best choice of the optimization goal parameter is *energy storage efficiency*. As we shall try to show below, this optimization parameter may turn out to be more informative than the generally accepted parameter of *action* selected by Lagrange. By a quality factor of the physical object, we mean the ratio of the total reactive power of the object's internal oscillations to the power of its irretrievable active losses. Additional benefits of this choice are some practical conclusions about the structure of complex physical systems, including the universe itself as the largest of them.

The newly introduced quality factor goal parameter may also be useful for the assessment of the physical object stability and for quantifying its lifetime. In addition, by calculating the quality parameter of a particular state of the system, it becomes possible to estimate the probability of this state being realized, and this allows us to make a prediction regarding the probability of a particular physical event realization. Each of us faces the question of the limits of our capabilities and the possibility to realize our desires.

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This eternal problem of free will has not found its final solution within the framework of philosophy. Despite the generally accepted view that philosophy is the science of all sciences, we allow ourselves to cast a glance at this problem from a somewhat unusual angle, based on the broad physical picture of the universe of which we are a part. Thus, we dare to assert the primacy of the laws of physics in the formation of the spiritual content of human knowledge. However, our goal is the opposite, and it comes down to an attempt to show the inextricable and fruitful connection between the *material* and the so-called *spiritual* counterparts of our reality.

3. Hydrodynamic model of the universe

Our experience teaches that any physical object is in the process of exchanging energy with the environment, which means that any object is an open system. Most if not all objects are slowly but surely losing some of their energy. However, taking the energy conservation principle as an axiom, we thereby idealize the universe and recognize its unique feature of being a closed system, which distinguishes it from all other physical objects. Perhaps this assumption is actually not entirely fair, and the universe does exchange energy with other similar formations, but this is not fundamentally important for us, dealing with physics of much smaller spatiotemporal scales. So, we will proceed with the working idea that the process of energy loss ends at the level of our universe, which completely retains all of its energy. Moreover, compliance with the principle of energy conservation must be understood not within the framework of a single object, but within the framework of the entire universe. This fact should be taken into account when we perform the energy balance for physical processes.

Discussing the topic of energy conservation, however, we did not bother till now to define what energy is. Unfortunately, this is a common practice, and, as far as we know, we will not find such a general definition for the energy concept in the modern physics literature. There are a variety of energy definitions useful for particular situations, but to the best of our knowledge, there is no general definition. This makes it necessary to give such a definition.

The hydrodynamic model of the universe assumes that the only form of energy that exists in the universe is the directed motion of some hypothetical *inviscid, incompressible, and inert substance*. Let's call it collectively *superfluid*, assuming that the superfluid possesses all listed above properties. According to this hypothesis, the concepts of energy and motion are inseparable. Once the energy is not destructible, the superfluid motion is perpetual. The absolute value of the superfluid velocity is a factor that determines the energy carried by the motion. The energy dependence on the square of the motion velocity may be derived following the logic of [2], Para.3, which was originally applied to the Lagrange function. "*We can now immediately draw some conclusions about the form of a Lagrange function of a freely moving material point in an inertial frame of reference. Homogeneity of space and time means that this function cannot explicitly contain either the radius vector* $\vec{\boldsymbol{q}}$ *of the point, or the time* t*, i.e.,* $L(q, \dot{q}, t)$ *is only a function of the speed* v*. Due to the isotropy of space, the Lagrange function cannot also depend on the direction vector* v*, so that is a function only of its absolute values, i.e., from the square* $\vec{\boldsymbol{v}}^2 = v^2$*:* $L = L(v^2)$". Following similar logic, we may conclude that the total energy of the superfluid substance freely moving with velocity v relative to the inertial frame of reference may be postulated as:

$$\delta E = \frac{1}{2}\rho_0 v^2 \delta V \qquad (1)$$

, where ρ_0 is a measure of the superfluid inertia that characterizes its ability to carry energy per unit volume, and δE is the amount of energy carried by volume δV occupied by the superfluid moving with the velocity v.

Form (1), representing the concept of energy as the equivalent of motion and as depending only on speed, apparently goes against the long-established tradition of representing the total energy as the sum of kinetic energy, depending only on speed, and potential energy, a function only of coordinates. Unfortunately, following this tradition, we find ourselves in a situation where the nature of potential energy remains mysterious, and the mechanism of its formation remains absolutely unclear.

A natural question arises: how does equation (1) reflect the contributions of the kinetic and potential energies to the total energy?

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In order to answer the above question, we have to comprehend that the universe is fractal, and in the stationary state, the universe's energy is redistributed between a variety of nested structures of different spatial scales. Planck's law of the spectral density of electromagnetic radiation emitted by a black body provides us a clear indication that the matter is quantized at the Planck scale, and that this is the utmost fine scale of the matter organization. In our experiments, we operate with probe instruments of subatomic scales, like electrons, protons, neutrons, or other elementary particles. The smallest available probe particle is more than 20 degrees larger than the Planck scale, and this makes experimental exploration of the finest-scale matter organization indirect and based on purely theoretical assumptions. However, theoretical assumptions must lead to conclusions matching the experimental results obtained in the course of large-scale experiments. According to the hydrodynamic model, the static structures of any spatial scale are composed of superfluid streams, whereas large-scale structures are composed of small-scale structures technically not detectable in our experience. The ultimately small structure is the Planck-scale vacuum lattice. In a static state, there is an energy balance between structures of all scales, but any dynamic excitation is associated with energy exchange between spatial scales. This makes the universe look like a clockwork in which seconds, minutes, hours, and larger scales are rigidly interconnected by gear mechanisms. Eventually, the large-scale excitation of the system reaches the scale of a vacuum lattice, in which all energy transformations are actually performed. Hence, the nature of macroscopic laws of physics cannot be revealed without a correct model of the Planck-scale structures. This paper is an initial step toward the development of such a model.

When we are talking about energy, we may mean either the energy stored in the static structures or the energy of dynamic interactions. Most of the physics laws deal with the energy of dynamic interactions, whereas the hidden energy of static structures appears as an integral parameter of the physical object involved in the interaction. For instance, in Newton's mechanics' the kinetic energy of a massive body m moving with velocity v equals $T = \frac{1}{2}mv^2$. In this equation, the velocity v is observable as a macroscopic characteristic of the moving body, while the mass m represents the energy stored in the small-scale structures including the Planck scale. Hence, when we try to understand the mechanisms of potential energy generation, we should clearly define what category of energy we mean: energy of macroscopic motion or energy of small-scale structures and events. The following discussion reveals that the difference between the kinetic and potential energies is that they reflect the energy stored in the superfluid motion in different spatial scales. Hence, let us learn more about what kind of motion it is.

At any spatial scale, including the Planck level, the natural (force-free) form of motion of an elementary superfluid volume is a helix with an inclination angle of 45°, in which the longitudinal $\vec{\boldsymbol{v}}_{\parallel}$ and transverse $\vec{\boldsymbol{v}}_{\perp}$ components of the superfluid velocity $\vec{\boldsymbol{v}}$ are equal:

$\vec{\boldsymbol{v}} = \vec{\boldsymbol{v}}_{\parallel} + \vec{\boldsymbol{v}}_{\perp}$, and

$\vec{\boldsymbol{v}}_{\parallel} = \vec{\boldsymbol{v}}_{\perp}$. (2a) (2b)

Accordingly, taking into account the orthogonality of the velocity longitudinal and transverse components, we can obtain the conventional expression for the total energy as the sum of the kinetic and potential energies:

$$\delta E = \frac{1}{2}\rho_0 v^2 \delta V = \frac{1}{2}\rho_0 (v_{\parallel}{}^2 + v_{\perp}{}^2)\delta V = \delta E_K + \delta E_P \,. \quad (3)$$

The helix form of the most basic element of structured matter corresponds to the form of the Beltrami streamline. As is known, the Beltrami flow is a solution to the homogeneous Euler equation describing the hydrodynamics of a perfectly inviscid incompressible inert fluid.

The velocity of moving massive bodies is the detectable expression of the kinetic energy. Although it originates at the Planck level, the kinetic motion is detectable since the energy of the longitudinal component $v_{\parallel}$ is transferred from one cell of the vacuum lattice to the other, while the motion direction is preserved, and the Planck-scale motion becomes visible.

In contrast, the component of rotational motion in the plane perpendicular to the helix axis is not transferred in space, and remains undetectable. The transverse component of the superfluid motion is the carrier of potential energy. The transverse motion does not participate in the energy large-scale translation

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in space and can only be detected by an observer of the microscopic Planck scale. Therefore, it is absolutely hidden for an observer of large-scale objects in both classical and quantum physics, because the dimensions (De Broglie length) of the smallest quantum object are many orders of magnitude greater than the Planck length. The impossibility of experimental observation of the potential energy generation mechanism is the main reason for the incomplete understanding of this concept in modern physics.
In addition, the question arises as to which reference frame should be measured the speed v?
A relatively recent work [3] is devoted to the collective behavior in a two-dimensional system of a self-propelled active fluid, the elements of which were given the energy of chaotic motion relative to each other as their initial state. Computer simulation showed interesting behavior of the system. It was shown in [3] that as a result of a transient process accompanied by multiple collisions of fluid elements, a hexagonal lattice structure of vortices is formed, which is in a stable equilibrium state. The authors come to the conclusion that "the emergence of a dynamic hexagonal vortex lattice state after an extended turbulent transient, can only be explained taking into account turbulent energy transfer across scales." That is, as a result of internal dynamics, a system of sporadically self-propelled superfluid elements spontaneously forms a stable ordered lattice of vortices. To the question of where the kinetic energy of the initially chaotic motion of the superfluid elements went, the authors answer that as a result of the transition process, this energy is concentrated in the vortices located in the lattice nodes. Moreover, the multiscale nature of the vortex architecture is noted. The vortex architecture incorporates a mechanism for energy exchange between structures of different space-time scales. Thus, the process of the emergence of order from chaos is clearly demonstrated, as Ilya Prigogine wrote about [4].
It is interesting to note the paradoxical role of collisions. On the one hand, they are the result of a chaotic movement, but on the other hand, it is thanks to collisions that an element of return motion arises, the culmination of which is a periodic and ordered reciprocating movement. Collisions are absolutely necessary for energy confinement in space. Each collision generates free energy characterized by a wide spectrum of frequencies thus contributing energy to nonlinearity effects. As we can learn from the hydrodynamic model of the universe, its practical solution to the problem of the collision phenomenon is the vortices formation. The vortices are an ideal absorber and reliable energy keeper in a wide frequency spectrum. Once arisen, coherent and strictly coordinated vortices rotation to a large extent prevents further random collisions that originally gave birth to the vortices. Hence the vortices generation is the most stable solution in this conflicting situation.
For each individual element of the superfluid, the resulting hexagonal lattice structure is a full-fledged reference frame, since this lattice structure contains the lion's share of the entire energy of the system in its coherent rotational movements. That is, the system of chaotically self-moving superfluid elements spontaneously generates for itself an absolute reference frame. This conclusion calls into question the generally accepted axiom about the absence of an absolute inertial frame, and with it the very principle of relativity generally accepted as an *"obvious" axiom* since the Galileo times. Accordingly, the generally accepted conviction about the physical laws' invariance when moving from one inertial frame of reference to another is also not justified in any way. The presence of an absolute reference frame makes it necessary to completely reconsider the Special Theory of Relativity validity and invites a new analysis of the physical phenomena in platforms moving relative to the absolute reference frame at speeds approaching the speed of light.
In addition, a *completely material absolute* reference system replaces the mystic concept of *space*, which is only a purely mathematical abstraction. The hydrodynamic model teaches that the moving Matter builds the Vacuum Structure, which then plays the role of Space as an effective instrument for the Matter's further transformations having a goal of energy conservation in the form of perpetual motion.
Why the superfluid was chosen in the model as the only energy carrier?
Only because the superfluid has unlimited possibilities to acquire any geometric forms of arbitrary spatial scale. Accordingly, the only and ultimate goal of the universe's existence is at any cost to preserve the energy originally handed to it. In accordance with the structured vacuum theory, all physical objects are phononic excitations of the vacuum hexagonal lattice structure, and consist of superfluid streamlines. In

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order to conserve energy in a given region of the absolute reference frame, superfluid flows must be cyclic. Thus, a certain energy density is preserved in a given volume of space. Any cyclic movement presupposes some transformation of one form of energy into another. In physics, it is customary to call these two forms of existence of energy *kinetic* and *potential* energy, and the cyclic transformation of one form of energy into another as *resonant* vibrations.
Cyclic energy transformations are a unique form of long-term energy storage in the universe, confined within a specific structure form. The cyclic transformations can be carried out between two extreme states of the system, whereas in one extreme state, the entire energy is stored in the form of kinetic energy, while in the second state, the total energy is potential. The energy conversions in a course of resonant oscillations use the mechanism available in the system degrees of freedom. The energy conversions may be either within the frame of the same space-time scale, or in accordance with the degree of freedom of the system energetically coupling the states of two adjacent levels. Thus, there are two classes of physical phenomena:

- resonant oscillations of relatively weak energy content between system states belonging to the same scale, and
- resonant oscillations involving a much greater exchange energy, taking place between the states belonging to two different spatial scales.

The first category of oscillations is called frequency resonance, and electromagnetic waves are an example of it. Accordingly, there are also fewer explored purely gravitational oscillations.
The second kind of transformation is known as *spatial resonance*, and it serves as the mechanism for creating massive particles, of which the most elementary are quarks. This type of resonant energy conversion of electromagnetic energy to gravitational energy generates phenomena of gravity mass, an inert mass, electric charge, and magnetic moment. Mechanisms of spatial resonance are the least studied in modern physics, although they are responsible for the gravity and inertia phenomena known from Newton's times. These exchange mechanisms are introduced in modern physics as their equivalents, so-called *energy exchange particles*, like gluons and Higgs particles.

4. The modified concept of free energy

It is commonly implied that the free energy is part of the system's total energy able to do some work. The theory of structured vacuum employs the concept of distributed kinetic and potential energies (see Appendix A). The theory distinguishes four types of fundamental energy densities spread unevenly along fine structures of superfluid streamlines comprising each physical object:

- potential gravitational energy, responsible for gravity effects;
- kinetic gravitational energy, responsible for the massive particles' inertness;
- potential electromagnetic energy, manifesting itself in electric charge phenomenon and electric fields;
- kinetic electromagnetic energy, manifesting itself as magnetic moment and magnetic field phenomena.

As can be seen, there are two kinds of kinetic and two types of potential energies.

Each one of the four energy types may be described by its density function of the spatial coordinate s and time t. Correspondingly, the free energy density functions of the s and t coordinates may be defined as a difference between any type of kinetic and any type of potential energy density. The structured vacuum theory shows that all particles have one-dimensional contour-like structures. Hence the free energy density function is defined along all contour-like structures comprising each elementary particle.

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In order to more deeply comprehend the real meaning of the term *free energy of the physical object*, we should take into account that:

a) the *work* may be done by the object only in the course of its interaction with some other exterior object;
b) each interaction has the goal to bind free kinetic energy of any kind (either gravitational or electromagnetic) to an equal amount of free potential energy of any kind. In this way, the amount of the system's free energy able to perform work is systematically reduced;
c) the physical object may be involved in *long-range* interactions with other exterior objects only if there is a globally nonzero amount of kinetic or potential energy of some kind within its structure. Once this condition is satisfied, both interacting objects start resonant energy exchange forming a global oscillator;
d) any *short-range* interaction between physical objects is due to the existence of their structures of sections featuring local nonzero densities of imbalanced kinetic and potential energies. Once this condition of the symmetry breaking is satisfied, both objects start resonant energy exchange forming a local oscillator.

Quarks may serve us as an ideal example of a physical object able to be involved in global (long-range) and local (short-range) interactions. It has sections of its structure confining locally and globally not-compensated free energy of all four types listed above. It is easy to understand that such particle is able to be involved in long-range and short-range interactions. The long-range interactions are covered by well-known Newton's gravity attraction law, the second law of Newton's mechanics, the Coulomb electric interaction law, and the magnetic induction law. The local near-field interactions are responsible for nuclear forces. This approach makes an unnecessary introduction to the model of gluon particles.

In modern quantum mechanics, which is currently dominated by the Copenhagen interpretation of quantum phenomena, all elementary particles are considered point objects. The total energy of the system of N particles is the sum of its kinetic energy $\mathcal{T}(\dot{q},t) = \sum_i \frac{m_i \dot{q}_i^{\,2}}{2}$ and potential energy $E = \mathcal{T}(\dot{q},t) + \mathcal{U}(q,t)$.

Accordingly, the instantaneous power of the system's evolutionary processes can be defined as

$$P_{TOT} = \frac{d}{dt}[\mathcal{T}(\dot{q},t) + \mathcal{U}(q,t)]. \quad (4)$$

When calculating the potential energy of $\mathcal{U}(q,t)$ the energy of particle-particle interaction is taken into account. In quantum mechanics the kinetic $\mathcal{T}(\dot{q},t)$ and potential $\mathcal{U}(q,t)$ energies of the particles are time-dependent integral parameters of the entire particle, and a particle is a zero-dimensional object. However, assuming that the particles are point objects, we neglect the possible near-zone effects that may arise due to the spatial distribution of the particle's kinetic and potential energies within their structures. To get around this difficulty, quantum theory has to introduce the concept of special particles that carry the binding, or energy exchange, energy. These particles are responsible to particle-to-particle short-range interaction energy. An example of such a particle is the gluon.

The structured vacuum theory [5] shows that all particles have one-dimensional contour-like structures. Hence the free energy density function is defined along all contour-like structures comprising each elementary particle. Accordingly, since all physical objects have a spatial extension, the following functions of the spatial coordinates *s*, measured along the curvilinear coordinates associated with the object's spatial structure, were introduced:

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- local density of kinetic energy $\mathrm{T}(\dot{s}, t)$ as a function of the velocity $\dot{s}$ of the excitation wave propagating along the coordinate s. The coordinate s is defined along the one-dimensional contour C of each elementary particle, and
- the *local density of potential energy* $U(s,t)$, and
- the *local density Lagrange function* $L(s,\dot{q},t) = T(\dot{s},t) - U(s,t)$, having the physical meaning of free energy density. The free energy density expresses the symmetry breaking between local densities of kinetic and potential energies, and is responsible for the perpetual energy transformation within the particle frame.

When calculating the losses of massive elementary particles, we rely on the fact that the losses are the result of the particle interactions with the outside world. In turn, the particle's interaction with the surrounding environment occurs due to the presence in its distributed structure of sections featuring symmetry breaking.

The inner process of bidirectional kinetic and potential reactive energies conversions generates oscillations at the particle's De Broglie. The inner energy conversion mechanism is a wavelike process propagating along the circular structures of massive elementary particles. Actually, structures known as zero-mass and massive elementary particles are generated as the one-dimensional (curvilinear) sites supporting these resonant transformations and behaving as transmission lines carrying the wave of harmonic excitation at the particle's De Broglie frequency f.

Hence, the distributed Lagrange function $L(s,\dot{s},t)$, which in essence describes the spatial distribution of imbalance of local kinetic and potential energies, is interpreted as a spatial distribution of *free energy density* within the particle's structure and may be decomposed to two components: (a) density of *reactive* free energy $X_{FREE} = Im(L(s,\dot{s},t))$, and (b) density of irreversible for the particle *active* losses $R_{FREE} = Re(L(s,\dot{s},t))$. Only active losses steadily degrade the particle's energy, whereas the density of the reactive free energy changes its sign along the particle structure, while the integral value of the reactive free energy averaged over the period of inner oscillations, or along the entire contour of the particle structure, always remains zero.

Accordingly, the integral kinetic, potential, and free energies of the entire isolated particle may be then defined in terms of the newly defined local energy density functions as:

$$\mathcal{T}(\dot{q},t) = \int_C T(s,\dot{q},t)ds \tag{5}$$

$$\mathcal{U}(q,t) = \int_C U(s,q,t)ds \tag{6}$$

, and the total power of active losses is

$$\wp_{LOSS}(q,\dot{q},t) = Re\frac{d}{dt}\mathcal{L}(q,\dot{q},t) = Re\frac{d}{dt}\int_C L(s,\dot{q},t)ds = Re\frac{d}{dt}\int_C [T(\dot{s},t) - U(s,t)]ds = Re\frac{d}{dt}[\mathcal{T}(\dot{q},t) - \mathcal{U}(q,t)]. \tag{7}$$

Accordingly, the objective optimization functional for an isolated particle is its quality factor

$$Q = \frac{\mathcal{T}(\dot{q},t)+\mathcal{U}(q,t).}{Re\frac{d}{dt}[\mathcal{T}(\dot{q},t)-\mathcal{U}(q,t)]}. \tag{8}$$

Note: In the structured vacuum theory, $T(s,\dot{q},t)$ kinetic and $U(s,q,t)$ potential energies of the elementary particle are defined as contour integrals along the particle's curvilinear double-helical helical or helical structure. The structures are composed of superfluid substance hydrodynamic flows. The integrands include squares of the flow longitudinal and transverse velocity components. Hence, the energy components are totally defined by the

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particle's geometry. This establishes a direct and unbreakable link between the particle's geometry and the assigned particle kinetic, potential, free, and total energies.
All physical theories adopt the energy conservation principle. Actually, this is an assumption that the total energy of the universe is conserved, and the universe is an isolated physical object. The universe is assumed to be the ultimate realization of the quality factor maximization principle and features apparently the unlimited value of its quality factor. This means that the energy exchange of the universe with other structures of similar spatiotemporal scale is neglected. The novel vacuum lattice theory, also appearing under the name of the structured vacuum theory, assumes that the entire universe possesses a certain finite amount of total energy, and that the universe's evolution has a single goal to store this energy in a given volume of space. It is realized that any universe's interactions with other similar systems are due to free energy at its boundaries. Hence, the strategy of the universe system is to reduce its free energy at the universe's spatial scale. Hence it is assumed that the energy conservation process is governed by the modified Hamilton principle in which the goal function has been changed: the universe and all its subsystems strive to the steepest descent to the state of its maximum energy storage efficiency, i.e., to the maximum value of the quality factor.

According to the model of the structured vacuum, the energy of the entire universe is stored in continuous streamlined flows of hypothetical substance behaving as an inviscid incompressible inert superfluid. The superfluid streamline flows are carriers of the entire universe's energy, and the optimal spatial distribution of streamlines serves as an ideal tool for the implementation of the Lagrange-Hamilton principle. Inviscid friction-free superfluid is the most appropriate substance to accomplish the mission of lossless dynamic energy conservation. Each stable physical object, including the entire universe, plays the role of energy reservoir for some finite amount of energy of its inner streams' circulations, while simultaneously possessing a minimal amount of free energy able to lose the energy due to external interactions. Each reservoir preserves some amount of the total energy E in the form of inner harmonic oscillations accompanied by an exchange between its inner kinetic T and potential U energy categories.

Until now, the Lagrange-Hamilton principle operating in terms of potential and kinetic energies has been used in physics with some degree of formality. Without defining what kinetic and potential energies actually are, we perceived this principle as an abstract algorithm that has a spirit but does not have its *material* embodiment. In other words, the concepts of kinetic and potential energies were perceived as some artificial characteristics introduced into their lexicon by people for their own convenience. This did not necessarily mean that the specific material embodiment of these energy concepts really exists. In contrast, the theory [5] provides definitions of kinetic and potential energies as energies carried by the longitudinal and transverse velocity components of a material superfluid substance. These definitions transform originally abstract energy concepts and associate them with dynamic parameters of real material structures.

It is commonly implied that the free energy is part of the system's total energy able to do some work. The theory of structured vacuum employs the concept of distributed kinetic and potential energies. The theory distinguishes four types of fundamental energy densities spread unevenly along fine structures of the superfluid streamlines comprising each physical object:

- potential gravitational energy, responsible for gravity effects;
- kinetic gravitational energy, responsible for the massive particles' inertness;
- potential electromagnetic energy, manifesting itself in electric charge phenomenon and electric fields;
- kinetic electromagnetic energy, manifesting itself as magnetic moment and magnetic field phenomena.

As can be seen, there are two kinds of kinetic and two types of potential energies.

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The free energy concept is the measure of either local or global imbalance of kinetic and potential energies. It enables quantization of the general concept of symmetry breaking. In order to more deeply comprehend the real meaning of the term *free energy of the physical object*, we should take into account that:

a) the *work* may be done by the object only in the course of the object's interaction with some other exterior object. The interaction may occur only if there is either local or global free energy carried by the superfluid within the object's inner structure;
b) each interaction has the goal to bind free *kinetic* energy of any kind, either gravitational or electromagnetic, to an equal amount of free potential energy of any kind. This means that interactions may be of four categories (i) kinetic gravitational energy and potential gravitational energy, (ii) kinetic electromagnetic energy and potential electromagnetic energy, (iii) kinetic gravitational energy and potential electromagnetic energy, and (iv) kinetic electromagnetic energy and potential gravitational energy. Historically, each category of the resonant interactions was described by a separate physics law which was considered fundamental. The process of this bidirectional energy exchange is named *resonance*. Once the resonant interaction is established, the amount of the system's free energy able to perform work is reduced by an amount of the energy involved in the resonant interaction;
c) the physical object may be involved in far-range interactions with other exterior objects only if there is a globally (within the frame of the particle's structure) nonzero amount of kinetic or potential energy of some kind. Once this condition is satisfied, both objects start resonant energy exchange forming a long-range oscillator;
d) any short-range interaction between physical objects is due to the existence in their structures of sections featuring local nonzero densities of kinetic and potential energies. Once this condition is satisfied, both objects start resonant energy exchange forming a local short-range oscillator. This leads to the agglomeration of two initially isolated particles accompanied by the particles reshaping and dramatic reduction of their free energy.

Quarks may serve us as an ideal example of a physical object able to be involved in either global (long-range) or local (short-range) interactions. It has sections in its structure confining locally and globally not-compensated free energy of all four types listed above. Naturally, such particle is able to be involved in long-range and short-range interactions. The long-range interactions are covered by well-known Newton's gravity attraction law, the second law of Newton's mechanics, the Coulomb electric interaction law, and the magnetic induction law. The local near-field interactions are responsible for strong nuclear forces. The described above model makes an unnecessary introduction of gluon particles as responsible for the short-range energy exchange.

5. Main stages of the vacuum lattice genesis

The unperturbed vacuum appears to be a hexagonal lattice of vortices interconnected by double-helical flows permanently emitting randomized flows and condensing them back. This paragraph provides a brief characteristic of each one of the ordered and random states.

Random vs. ordered states

The starting point for the universe's development is the completely chaotic movement of the primordial inviscid non-compressible and inert substance, which may also be named superfluid. The entire energy in the universe exists only in the form of superfluid motion. Inertness $\rho_0 = \frac{2 \cdot \delta E}{v^2 \delta V}$ is the measure of the superfluid ability to store the energy δE in its volume δV moving with the velocity v relative to some *absolute reference system* coinciding with the center of the inertness of the universe. The ultimate goal of the universe's steepest dynamical optimization is to preserve the energy of motion initially given to it to the maximum possible extent.

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The arbitrary system of superfluid flows may be decomposed into randomized and ordered fractions. Each fraction in its extreme realization, either absolutely random or ideally ordered, fully complies with the commandment of the Hamilton principle to be at the minimum level of its free energy, since neither random nor ordered part of their total energy is able to perform some useful work. The surrounding physical reality is a compromise between these extreme states.

By the method of numerical experiment, the authors of [3] demonstrate how an initial completely chaotic system of self-propelled superfluid flows spontaneously evolves to an almost completely ordered lattice of vortices. This experiment demonstrates that the absolutely random state is not stable, while the utmost ordered state of the matter organization is lattices. Inner collisions within the random state give birth to vortex elements, which are indivisible parts of the ordered lattice. The vortex permanently generates and emits a certain relatively small amount of energy of chaotic fraction. A small amount of chaos is absolutely necessary to keep the vortices stable and immune to external disturbances. The vortices stability is achieved as a dynamic balance of two oppositely directed processes, one of which is the emission of chaos energy from the ordered phase, and the second is the condensation of a random phase back into the ordered state. Under equilibrium conditions, full dynamic compensation of energy losses of vortices is achieved by reverse condensation.

The random state appears to be unstable and inevitably condensates to the ordered state. The ordered state experiences a dispersion process permanently losing part of its energy. This bidirectional everlasting energy exchange leads to a synergetic balance between the ordered fraction in the form of particles and waves and randomized energy flows in the form of electromagnetic and gravitational backgrounds. There are also the reverse processes of random fraction condensation to crystalline apparently frozen structures. This leads to the concentration of the dominant energy in the ordered state, whereas the random energy plays the role of catalyst and building material in the condensation process. Transformations of the ordered energy to the random fraction are due to topological restrictions embedded into the ordered coherent structures, which inevitably generate inner collisions and release of randomized free energy featuring broadband spectral density. Similarly, random flows have a nonzero probability of regeneration back to ordered crystalline structures. The collisions and condensation processes are the driving factor of the universal system evolution and are absolutely necessary elements eliminating the universe's thermal death by randomization or its complete crystallization. The ordered fraction is readily observable and is traditionally the focus of physical research. All physical objects, including elementary particles, are stable due to the existence of a high-quality internal resonant process. In other words, any stable particle has a structure supporting harmonic oscillations at its De Broglie frequency. For larger-scale observers using instruments featuring sampling rates much below the De Broglie frequency of the observed particles, such particles are an ideal implementation of the Hamilton principle, since the amount of free energy averaged along the period of De Broglie oscillation is optimally close to zero. Deviation from an ideal balance between the stored averaged kinetic and potential energies is either due to excitation or particle losses. The above consideration justifies our focus on the ordered resonant objects in our further model presentation. Hence exploration of the random fraction, so important in the system evolution, is practically out of the scope of this paper.

6. The system's strive for the optimally large quality factor and its consequences

The main premise of the presented hydrodynamic model is that the purpose of the universe's genesis and existence is to store its energy. Hence it is rational to introduce the *quality factor* of the system as a goal parameter for the system's persistent optimization. By the quality factor of the physical system, we mean the ratio of the total reactive power of the system's internal oscillations to the active power of the system's irreversible losses. The quality factor can be increased either by increasing the inner reactive power and/or by reducing active power losses. It may be shown that such phenomena as the spontaneous formation of resonant objects, equal distribution of energy between degrees of freedom, agglomeration of resonant objects into clusters, and the formation of continuous matrix structures are just techniques aimed at increasing the quality factor of the dynamic energy storage by the moving superfluid matter localized in a given volume in space. An additional effective technique is the formation of multiscale fractal structures. In this case, the maximum possible

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energy density and minimal losses are achieved by two methods: (a) structures of different scales occupy the same volume but carry much more energy, and (b) in multi-scale fractal structures, the overall system losses are minimized since losses of numerous smaller-scale resonant objects are utilized for the creation of a single larger-scale resonant object.

At this point, we may reformulate the traditional Lagrange-Hamilton optimization principle in terms of the new optimization goal of the system's energetic efficiency, i.e., the steepest ascent of its quality factor $Q = \frac{P_{TOT}}{P_{LOSS}}$. The commandment of the steepest quality factor maximization may be interpreted as the system trend to

a) the storage of the maximum possible amount of the total power P_{TOT} of the system's inner oscillations and
b) the minimization of the efflux power to the system surroundings, i.e., minimization of its losses P_{LOSS}.

This reformulation of the system dynamics algorithm allows us to take a different look at the system evolution and leads us to the clue on the optimal way to accomplish the optimal energy conservation task. The new formulation of the Lagrange-Hamilton principle appears to be very fruitful by revealing to us the real motivation standing behind several well-known phenomena:

a) **spontaneous generation of natural oscillators:** this is the basic method to bind some amount of free *kinetic* energy, either gravitational or electromagnetic, and the same amount of *potential* energy, either gravitational or electromagnetic, forming a basic harmonic oscillator. Two types of resonant oscillators were considered above in Para. 1 of this paper. The resonance phenomenon appears to be the most basic implementation of the optimization idea of the system's minimum free energy and the equivalent idea of the system's maximum quality factor;

b) **the abundance of coherent collective oscillations in nature:** global coherent oscillations are the best possible modus operandi for optimally low-loss systems. Coherence of neighboring mechanical oscillators prevents the collision effects within the system and minimizes the inner free energy generation to its optimal value;

c) **the abundance of systems with multiple-scale hierarchal nested architecture:** the system's optimal structure featuring maximal energy density and minimal loss must have multiple-scale nested architecture composed of the ordered structures of different scales interleaved and energetically interconnected by means of the randomized energy fraction. The spatial resonance employs potential-to-kinetic (and vice versa) energy conversions between two system excitation states belonging to two adjacent scales;

d) **the systems strive to free energy reduction by forming isolated and clustered resonant structures:** superfluid ordered flows belonging to each spatial scale should strive to divide equally their total energy between all available degrees of freedom;

e) **enhanced vitality of systems with a larger number of degrees of freedom:** longevity and stability advantages of multiple-frequency nonlinear resonators over linear resonators.

All these far-going conclusions shall be supported by the following discussion.

The reference [6] concludes that object stability is referred to the tendency of the object to return to its previous position or move away from its original position as the reaction to impact imposed by external excitation. Using

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the above definition as a practical guide, we may conclude that only those objects have the right to be temporally stable, which features the greatest possible ratio of the stored total power to its power loss, or to the system power dissipation. Moreover, such an object not only *can*, but it *must* exist in reality, because it optimally implements the energy conservation and Lagrange-Hamilton principles. Not surprising is that high-quality resonators are the most efficient energy attractors. The external disturbance enriches the spectrum by components which, after the disturbance was eventually terminated, are readily absorbed back within the attractor.

In our everyday reality, we encounter many such events that are obliged to happen. We have become so accustomed to this that we have ceased to ask the "naive" question of why these phenomena actually occur. For example, a massive object placed in a nonuniform gravitational field with natural inevitability and spontaneity starts moving with acceleration in the direction pointed by the gradient vector of gravitational energy density. The presented here structured vacuum theory does not limit itself to mere prediction of this event, but also reveals its hidden mechanism. Thus, armed with the new vision of reality, we become complete masters of the situation and may start not only to analyze, but also to create favorable situations for the physical system to behave in one way or another, and events to happen.

Applying the principles listed above to the process of matter structuring, we arrive at the following algorithm for the behavior of the system composed of the superfluid flows:

a) Creation of elementary resonant structures

The creation of the vacuum lattice structure is a substantiation of energy quantization axioms. At the Planck level, a lattice vacuum structure is spontaneously created from superfluid streamlines. All elementary cells of this structure are contours resonated off the Planck frequency, closely energetically connected in such a way that the energy of coherent oscillation of the common resonant frequency is transferred from one cell to a neighbor cell in just half of the Planck oscillation period. The Planck parameters, like frequency, superfluid velocity, etc. are all dictated by the energy density in a given spatial location. Value of the superfluid density ρ_0 specified in Para.1 may be derived from the Planck constant h;

b) The principle of using all available in the system degrees of freedom to condense energy

In order to further compress the inner energy, each cell of the vacuum structure maintains oscillations of both antisymmetric (longitudinal) and symmetric (longitudinal) vibrations of its constituent double helix. Each Planck cell provides a mechanism for the implementation of the spatial resonance of these two oscillation modes of the double helix. Namely, the kinetic component of the free energy of the antisymmetric mode is transformed with maximum completeness into the potential energy of the symmetric mode of vibrations of the double helix in the course of only one period of vibration of the unit cell. Simultaneously with this transformation, the reverse transformation of the potential energy of the antisymmetric mode into the kinetic energy of the symmetric mode takes place.

There are two additional degrees of freedom for frequency resonance: (a) kinetic electromagnetic energy is transformed to potential electromagnetic energy, and (b) kinetic gravitational energy is transformed to potential gravitational energy;

c) The principle of using multi-scale nested structures for compaction and long-term energy storage.

Using the superfluid properties to create streamlines of arbitrarily small physical sizes, the system opens up the possibility of creating a large number of stable nested matrix structures of different scales within the same volume of space.

The long-term observations of the universe led to a conclusion about its hierarchal multiple-scale architecture in which any large-scale (macroscopic) physical object is constructed of a large number of smaller-scale

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(microscopic) objects. This appears as the general principle of matter organization. For instance, compliance with this general rule is observed in the atomistic structure of gaseous, liquid, and solid matter, and in the cellular structure of living systems. Full characterization of any complex physical object needs observation of all its substructures belonging to consequent nested spatiotemporal scales. However, modern physics prefers to postulate laws operating on a single space-time scale, thereby avoiding the need to consider the mechanisms by which these laws operate. Members of each pair of adjacent scales may be addressed as global and local. Object evolution occurs simultaneously in all scales, and a comprehensive analysis of the object dynamics should take into account energy interaction between the global (macroscopic) and local (microscopic) scales. The short-term changes become apparent on a small scale, and it takes considerable time to appear on a larger scale. Moreover, mechanisms of energy conversion are always hidden in the small-scale structure, and the study of the consequent large-scale processes is fruitless, purely phenomenological, and will never lead to a real understanding of physical phenomena.

One of the main fallacies of some physical theories is that the above consideration is not taken into account. Two examples of such theories are hydrodynamics and quantum mechanics. In both cases, the object of study is analyzed by the theories as a single-scale system. This does not allow a comprehensive description or reasonable explanation of the experimental results. Instead of considering the existence of additional fine structures, the theories choose to formulate rules and axioms, while real mechanisms remain unrevealed. So, for example, modern hydrodynamics operates exclusively with the Navier-Stokes equation, completely neglecting the fact that real physical liquid has a discrete molecular structure, and the kinetic-to-potential energy transformations occur at the scale of intermolecular interaction [7]. In the case of quantum mechanics, the discrete crystalline structure of the Planck-scale vacuum lattice is overlooked, which makes impossible rational substantiation of the quantum mechanics axioms and explanation of its hidden mechanisms.

Our basic assumption was that the final goal of conduct of all physical objects is energy conservation at the superior level of the entire universe. With this in mind, we may conclude that the system's strive for the minimum of free energy is implemented both locally and globally, but global optimization goals dominate local ones. As a result, local deviations within the multiple-scale system may be allowed if this tactic leads to the strategic steepest descent of global free energy. In other words, the lowest level of free energy at any given spatial scale is achieved at the price of shorter-term deviations from zero free energy at the smaller spatiotemporal scale. Hence the perpetual motion observed elsewhere in the universe is a part of these oscillations binding the free energy of the universe within countless resonant processes with nearly zero free energy.

As an example of such a resonator, we may consider an elementary system composed of the simple spring-and-mass oscillator isolated from any external factor. One side of the elastic spring is firmly attached to some motionless support, while the other side is loaded by a massive ball. The system is charged by some finite amount of initial energy, and the oscillator performs harmonic force-free oscillations at a single self-resonance frequency. At two specific occasions occurring twice per period, the kinetic and potential energies of the oscillator are balanced. At any other moment for the observer belonging to the same with the oscillator spatiotemporal scale, the system reactive kinetic and potential energies are imbalanced, and the system free energy $L(s, \dot{s}, t) = T(\dot{s}, t) - U(s, t)$ is not zero and periodically changes its sign from positive to negative and vice versa. In this formula s and $\dot{s}$ are the ball's instant coordinate and velocity, respectively. But for distant large-scale observers monitoring the system for periods of time much longer than the oscillation period, the averaged imbalance of reactive kinetic and potential energies is diminished to practically zero, except for the relatively small amount of active power lost in irrevocable energy dissipation.

At this point, we are able to formulate the rule according to which the large-scale temporal stability and energy storage capability of the macroscopic scale of the system are achieved at the price of harmonic oscillations at its microscopic level. We came to the conclusion that the global free energy of the large-scale objects, averaged over a large period of time, is practically diminished to the optimal level corresponding to the system's active losses, and this fact justifies short-term deviations from the minimum of free energy at smaller scales.

d) Stable physical objects as resonant structures

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According to the Lagrange principle, which itself follows from the principle of energy conservation, any local lack of balance between densities of kinetic and potential energies within the physical system gives birth to the system's ability to do some action (or useful work) in a course of its recovery to the desired state of balance. The most effective method of restoring the balance, while conserving the motion energy within the system, is the method of energy storage in the form of resonant oscillations. By definition, resonance is the process of gradual periodical and bidirectional transformations of a finite amount of kinetic energy into an equal amount of potential energy. The structure of flows along which the resonant transformation of energy takes place is called the resonant object. In such an object as an elementary particle, the balance of kinetic and potential energies is experimentally observed by the large-scale observer with a temporal resolution many orders greater than the period of the Planck-scale resonant oscillations. For such an observer the internal non-equilibrium states within the object are indistinguishable, and the entire object is perceived as stable energy storage. Typically, the elementary particle is characterized by its integral parameters like mass, electric charge, magnetic spin, etc. The physical paradigm of the proposed theory of the structured vacuum enables penetration within the particle structure and its dynamics.

e) Two types of resonance as ideal mechanisms for energy storage

Lossless resonance is a process in which some amount of energy is periodically exchanged back and forth between its kinetic and potential forms. Stable physical objects are structures supporting some kind of resonance. The formation of multiscale matrix structures allows the realization of two types of resonances: frequency and spatial. In objects supporting frequency resonance, a certain amount of kinetic energy is converted into an equal amount of potential energy, whereas the transformation takes place between the energies of the longitudinal and transverse components of the helical flow velocity. The transformation occurs between the longitudinal and transverse flow components of the same spatial scale.

The second type of resonance is called spatial, and it converts in one exchange process the kinetic energy of an antisymmetric mode of one scale with the potential energy of a symmetric excitation mode of a larger scale. Spatial resonance links the flow energy of one scale with the flow energy of another scale. This process allows optimization of the system quality factor not only with the help of energy transformations between flows of a certain spatial scale but also from one spatial scale to flows hidden deeply within the matter's fine structure. Spatial resonance involved processes occurring at two frequencies differing by several orders of magnitude.

An example of frequency resonance is electromagnetic phenomena, e.g., a helical photon excitation of the vacuum lattice. Similarly, there is its dual twin in the form of a helical gravitational particle carrying the vector of gravitational momentum propagating in space.

f) Sufficiency of three spatial dimensions

In compliance with the requirement in the shortest time to achieve the ultimate goal of motion energy conservation, the universe limits its formation to three spatial dimensions. Three spatial dimensions of space turn out to be sufficient to prevent collisions of the substance flows, which would be otherwise inevitable in two-dimensional and one-dimensional spaces.

7. The emergence of streamlined flows

Looking for a way to minimize flow collisions, always associated with poorly controlled energy dispersion and increased losses, each stable system in its equilibrium stationary state is composed of the substance flows shaped as streamlines. Moreover, in order to avoid collisions, the velocities of flows belonging to all spatial scales are uniform. Experimentally derived light velocity enables us to assert that in the unperturbed vacuum, the superfluid substance flows with velocity, which longitudinal component equal approximately to $c=3\cdot10^8$m/sec.

The process of the universe system optimization is culminated by a generation of the vacuum lattice structure and consequent structuring of the remnant after that energy in the form of isolated elementary particles.

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From the same consideration of avoiding collisions, initially, chaotic flows acquire over time the character of streamlined flows. This technique allows the simultaneous movement of the substance streams in opposite directions while avoiding a collision. Thus, striving for minimalism, the system avoids creating unnecessary degrees of freedom.

In the hydrodynamic model of the universe, we adopt the basic element of the matter structure superfluid flow in the form of two oppositely directed and ideally anti-symmetric twisted helical streams. This double-helical structure features identical values of transverse and longitudinal velocity components. These elementary bricks of double-helical superfluid flow, as illustrated below in Fig. 1, optimally fill the entire universe volume in the pattern minimizing the universe quality factor $Q = \frac{P_{stored}}{P_{loss}}$, the ratio of the universe inner power to its lost power. We should underline that the energy flows along helical trajectories in 3D lattices are not associated with the net large-scale superfluid translational motion. In each Planck cell of the vacuum lattice, the superfluid flow in the forward direction is compensated by the flow of the same amount of superfluid in the opposite direction. The helical flow may be decomposed into longitudinal and transverse velocity components. Correspondingly, energy storage is implemented by means of longitudinal and transverse flow components. Further members of this decomposition are distinguished as carriers of kinetic and potential energies, respectively.
Fig. 2. shows only one member of the elementary twisted pair, which performs 360° azimuthal rotation and simultaneous translational motion along the central axis $\hat{\boldsymbol{z}}_0$. As shown in the picture, superfluid flows are assumed to be stream-like. All streams have a uniform cross-section S_0 and constant per-unit-length superfluid density ρ_0.

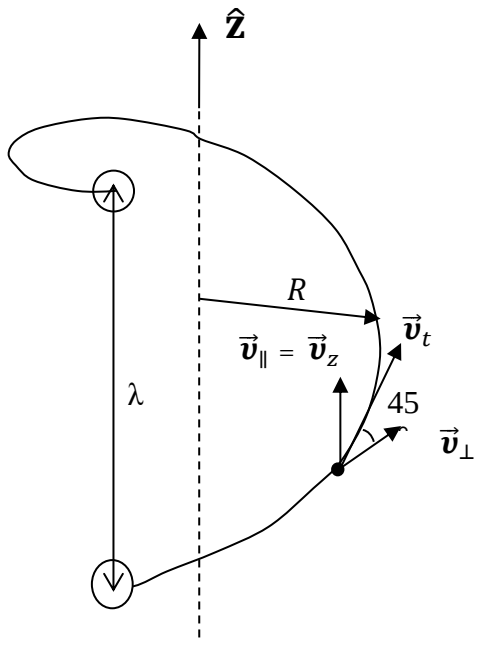

Fig. 1 The one-turn section of the helical streamline is the most primitive resonant structure carrying equal amounts of kinetic and potential energies. The kinetic and potential energies are carried by the longitudinal and transverse velocity components, respectively.

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At each spatiotemporal scale of the matter organization formation of elementary double-helical superfluid flows is the natural way to achieve the matter state of minimal free energy. Any helical stream structure has spatial period λ. At arbitrary wavelength λ, each pitch of the helical flow is the elementary brick carrying the quantum of energy of this specific spectral component. This observation supports and generalizes Planck's postulate on quantization of the electromagnetic energy, and appears to be applicable to flows carrying either gravitation or electromagnetic energy contents. At the special Planck frequency, we add subscript index 0 to all parameters of the double-helical flows. Correspondingly, the Planck length will be denoted as λ_0.

The Helmholtz decomposition of the total velocity superfluid vector $\vec{\mathbf{v}}_\mathbf{t}$ to orthogonal translational and rotational motions is able to describe motion along arbitrary curvilinear trajectories with varying curvature. The unperturbed stationary superfluid, flows have time-invariant geometrical shapes and constant curvature. The coordinates of each infinitesimally small parcel of the moving superfluid are described by periodical functions. Each double-helical flow belongs to some cylindrical surface. Hence coordinates of any infinitesimally small segment of superfluid helical flow propagating in the positive direction along the axis $\hat{\boldsymbol{z}}$ along the cylindrical surface with constant radius R, may be written as functions of the time parameter t:

$$\begin{gathered} x^+(t) = R \cdot cos(2\pi \cdot t/T + \varphi) = R \cdot cos(\Omega t + \varphi) \\ y^+(t) = R \cdot sin\left(2\pi \cdot \frac{t}{T} + \varphi\right) = R \cdot sin(\Omega t + \varphi) \\ z^+(t) = \lambda \cdot \frac{t}{T} = v_\parallel \cdot t \end{gathered} \tag{9}$$

, where R is the helix radius, $\Omega = 2\pi F = 2\pi/T$ is the angular frequency of the transverse rotation around the propagation axis, and φ is the arbitrary phase. In the unperturbed state of the helix, the segment simultaneously rotates with the constant angular frequency Ω around the propagation axis $\hat{\boldsymbol{z}}$ and moves with the constant longitudinal velocity $v_{\parallel 0}$ along this axis. Amplitudes of transverse and longitudinal components of the segment velocity in the unperturbed helical flow are constant and are equal to $\upsilon_\perp = \frac{2\pi \mathrm{R}}{T} = 2\pi \mathrm{R}F$, and $v_\parallel = \frac{\lambda}{T}$ respectively, and $\upsilon_\perp = v_\parallel$. Hence the $\upsilon_\mathrm{t} = \sqrt{2}\upsilon_\parallel = \sqrt{2}\upsilon_\perp = \sqrt{2}\mathrm{c}$, and $\lambda = 2\pi \mathrm{R}$. Here c is the light velocity. Equal values of the translational and rotational velocities correspond to the state of equal kinetic and potential energies carried by the superfluid stream. This means that the total energy of the stream is, as expected, equally divided between two degrees of freedom. Correspondingly, the balance of kinetic and potential energies is ideal, and the Lagrangian takes the zero value.

Note: All elements of the double-helical streams may be either of right-hand *or* left-hand rotation in the plane transverse to the helix axis. Selection between the right and the left-hand rotation is an additional degree of freedom in the universe. This model arbitrarily adopts the right-hand rotation corresponding to what is known in the literature as the *matter*, whereas the left-hand rotation is assigned to the anti-matter option.

Each one of the two helical flows is the carrier of energy in the $\hat{\boldsymbol{z}}$ and $-\hat{\boldsymbol{z}}$ directions, but its net energy flux is completely balanced by the oppositely directed helical flow having the same handedness. As expected, the net energy translation in the unperturbed space is zero, although the total energy of both helical motions stored in the volume occupied by the double-helix is nonzero. This accomplishes the mission of the depicted above spatiotemporal organization: (a) the double-helical streams are the energy storage, but (b) they are not able to perform any work, i.e., have net zero free energy. Therefore, in the unperturbed state, the double-helical elementary brick is not detectable by our instruments and senses.

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In our further discussions, we adopt the superfluid double-helical streamlines as the *basic elements of the matter's structural organization*. In the unperturbed zero-level state, superfluid flows along two oppositely directed and ideally anti-symmetric double-helical streams with identical transverse and longitudinal velocities. In the local area of the universe, the superfluid total velocity $\vec{v}_t$ is dictated by the universe's energy density in the given location. Such a double-helical structure may be formed for any spatial period λ, wavelength, along the helical axis. Correspondingly the time period required for the element to cover the helix spatial period is

$$T = \frac{\lambda}{v_{\parallel}}, \tag{11}$$

, and the corresponding oscillation frequency for this spatial location and specific wavelength is

$$F = 1/T = \frac{v_{\parallel}}{\lambda} \tag{12}$$

These elementary bricks in the form of double-helical flows optimally fill the entire 3D vacuum volume in the pattern minimizing the vacuum-free energy. We should emphasize again that energy flow along double-helical trajectories builds an energetic basis for all larger-scale stable physical objects.
The transverse component of the helical trajectory with an inclination angle of 45° of an arbitrary point-like object around the central axis $\vec{\boldsymbol{z}}_0$, with a radial frequency of azimuthal rotation $\omega = 2\pi F$ and longitudinal velocity c in the positive direction, may be described by a complex scalar function

$$v_{\perp}(x,t) = c \cdot exp[j(\omega t - kz)]$$

, where $k = \frac{\omega}{c} = \frac{2\pi}{\lambda}$, and $\lambda = \frac{c}{F}$ is the wavelength, i.e., the pitch of the helical trajectory. The longitudinal velocity remains constant: $v_{\parallel}(t)$ =c.
Beltrami flow is absolutely lossless, and in the absence of collisions, is ideal for lossless energy storage. It implements the principle of equal energy division between available degrees of freedom, in this case between the energies of translational and rotational motions. The demand for the higher quality factor leads to higher energy density, if this energy compression is not accompanied by a proportional or even greater increase of losses. Spontaneous generation of straight double-helical structures is an ideal case when the stored energy is doubled, as compared with a single helix, while the additional losses do not emerge. This double-helical element is prevalent in all quantum-mechanical objects and is disturbed by either (a) the necessity for the *steepest* formation of confined resonant objects in the form of toroidal helix, or (b) by topological constraint like inevitable collisions, or (c) by agglomeration of two or more toroidal helices. For example, the agglomeration of two toroidal helices leads to their reshaping and generation of two vortices. In the course of the double-helical formation, the ideal lossless straight Beltrami flow is sacrificed in favor of the energy confinement in quite a stable resonant object. By the double-helical torus generation, the system pays the price of increased "radiation" losses but gains a great amount of stored energy of resonant oscillations supported by this ring resonator.

As a result of typologically inevitable collisions of double helices lying in the same planes, *vortices* are formed.

8. Definitions of gravitational, electromagnetic, kinetic, and potential constituents of the total energy

The motion of any elementary volume occupied by the superfluid substance can be decomposed to the longitudinal and transverse components of its velocity. Actually, this follows from the general principle according to which the energy of any system is equally divided between all degrees of freedom available within the system. According to the generally adopted consensus, the longitudinal component is recognized as responsible for the energy translation in space and is the carrier of kinetic energy. The transverse component of the flow velocity generates circular motions in a plane transverse to the direction of the translational motion, and it is responsible for the energy accumulation in a given spatial location. Hence it is the carrier of potential energy.

But in the system built of double-helices energy division between longitudinal and transverse flows is not the only degree of freedom. As we already noted above, any system tends to a uniform division of

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its own energy over orthogonal modes of its own oscillations. In a system whose main element is responsible for the energy redistribution is the double helix, it is most natural to expect the total energy to be divided equally also between the orthogonal modes of this symmetric transmission line composed of two helical streams. In this case, such modes are symmetric and asymmetric vibrations of the double-helical structure. In our model, the decomposition of the perturbed superfluid double-helical flows to symmetric and anti-symmetric flow patterns acquires deep physical significance of decomposition to electromagnetic and gravity energy carriers, respectively. In addition, the velocity vector of these propagation modes supported by double-helices may be decomposed into longitudinal and transverse components. As a result, all the excitations of the system, which is our universe, are divided equally between four fundamental categories of energy:

- kinetic component of gravitational energy;
- potential component of gravitational energy;
- kinetic part of electromagnetic energy, and finally
- potential part of electromagnetic energy.

In double-helical flows of the unperturbed vacuum, which is experimentally undetectable and traditionally neglected in modern physics, survives only in anti-symmetric gravitational mode. In contrast, in the vacuum excited states, which are the focus of our physical explorations, the velocity vector distribution along each helix is subject to deformations, and in the general case must be presented as a sum of four vector components:

$$\vec{\mathbf{v}}_{\mathrm{tot}}^{+/-} = \vec{\mathbf{v}}_{\mathrm{g}}^{\mathrm{p}} + \vec{\mathbf{v}}_{\mathrm{g}}^{\mathrm{k}} + \vec{\mathbf{v}}_{\mathrm{e}}^{\mathrm{p}} + \vec{\mathbf{v}}_{\mathrm{e}}^{\mathrm{k}}$$

, where indexes g, e, k, and p stand for gravity (anti-symmetric}, electromagnetic (symmetric), kinetic (longitudinal), and potential (transverse), respectively. Eventually, the total velocity vector field of the superfluid streams may be decomposed into four pairs of vector functions, each with its own physical significance:

a) the anti-symmetric longitudinal and transverse flow components which are carriers of kinetic and potential components of gravitational energy, respectively. The kinetic gravitational component $\vec{\mathbf{v}}_{\mathrm{g}}^{\mathrm{k}}$ gives birth to the phenomenon of inert mass, and this component is affected by the linear acceleration of any massive body and appears as a coefficient in the 2nd law of Newton‘s mechanics. The potential gravity component $\vec{\mathbf{v}}_{\mathrm{g}}^{\mathrm{p}}$ manifests itself as gravity mass, and may be affected by the rotation of any massive body. It is reflected in physics as a coefficient in Newton’s Gravity Law;
b) the symmetric longitudinal and transverse flow components are carriers of kinetic and, respectively, potential components of electromagnetic energy. The electromagnetic kinetic energy is carried by $\vec{\mathbf{v}}_{\mathrm{e}}^{\mathrm{k}}$, and manifests itself in our experiments as the magnetic energy, while the electromagnetic potential energy, carried by $\vec{\mathbf{v}}_{\mathrm{e}}^{\mathrm{p}}$, is the energy of electrical polarization of the vacuum lattice cells.

Eventually, we may summarize in the following table and in Fig. 2 that in essence, all our energy definitions, assign some physical significance to different topological and geometrical peculiarities of double-helical superfluid flows and their deformations. These definitions uniquely link the concept of energy with the geometry of particles, which are elementary physical objects. This clear translation of the geometrical shape to energy categories becomes difficult in more complex situations, when a large number of elementary particles are agglomerated to nuclei, atoms, molecules, etc. The agglomeration results in changes in the original shape of the particles and the appearance of vortices thus widening the frequency spectrum.

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Double-helical flow properties	Physical significance
Right-handed vs. left-handed helical rotations	Matter vs. antimatter energies
Longitudinal vs. transverse velocity component in helical flows	Kinetic vs. potential energy carriers
Symmetric vs. anti-symmetric propagation mode of the velocities in double-helical flows	Electromagnetic vs. gravitational energy carriers

Table A. Physical significance of parameters characterizing double-helical flows

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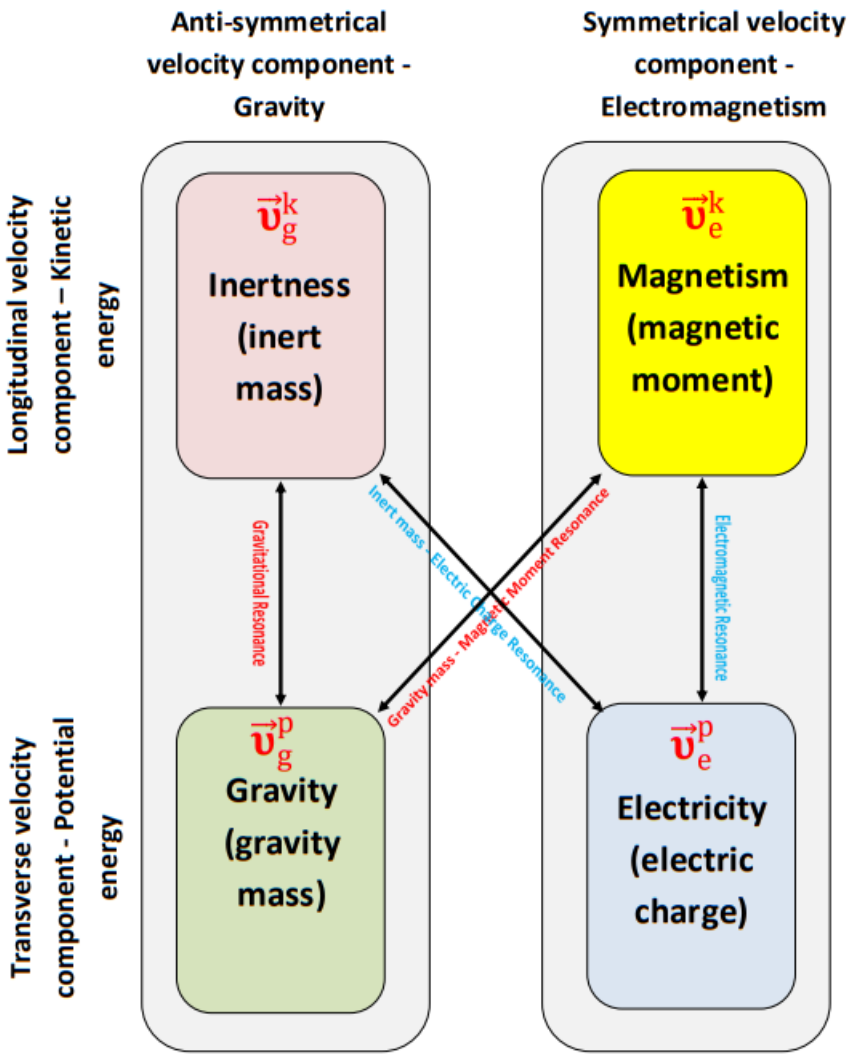

Fig. 2 Conversion of superfluid flow components to energy categories & resonant energy exchanges chart

9. Chain of the superfluid flow transformations in its self-structuring evolution and the vacuum lattice genesis

A relatively recent numerical simulation of a two-dimensional system of a self-propelled incompressible inviscid inert substance shows that the initial purely chaotic state is unstable, and the system spontaneously rolls down to the most ordered state, capable of providing an optimally high value of the system quality factor. The available numerical simulations are limited only to the two-dimensional case. For the 2D case, it was shown that after the transition process, the system spontaneously forms a stable hexagonal lattice of vortices. In this paragraph, we provide our vision of how these two-dimensional structures may be optimally packed in three-dimensional space. The resulting 3D architecture reflects the vacuum lattice structure.

Within each spatial scale, the lowest system losses are achieved by the generation of identical toroidal resonant structures and their further agglomeration. The agglomeration of toroidal resonant objects into extended

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hexagonal lattice structures is characteristic of objects of arbitrary resonant wavelength/frequency. Lattice structures corresponding to a variety of resonant frequencies occupy the same volume building the nested architecture. Against the background of the continuum of the nested lattice structures corresponding to the continuum of resonant frequencies, vacuum is a special lattice in which is realized the spatial resonance of the free electromagnetic energy of the Planck scale cells with the free gravitational energy of cells of a much smaller scale. On one hand, elementary cells of the lattice structure of a shorter wavelength involved in the spatial resonance feature a significantly higher energy density compared to cells of the Planck size. But on the other hand, the smaller-scale lattice contributes to the spatial resonance energy of the antisymmetric mode. The energy of the antisymmetric mode is confined in a limited and closed region between two helixes, and only a very small percentage of its energy is involved in spatial resonance. This allows the balance of the exchange energies of the antisymmetric (gravitational) oscillation mode of fine scale with the energy of the symmetric (electromagnetic) propagation mode of the much greater Planck scale.

In its search for the state with the maximum value of the quality factor, the superfluid flows undergo multiple transformations. The initial stage is the flow decomposition to double-helical streamlines resonating in a variety of spectral components. The bidirectional flow of the double-helices is due to collisions. These double-helices are then self-structured to closed-loop contours with a perimeter equal to the wavelength. For each wavelength, a plurality of identical contours tuned to the same resonance frequency are aggravated to a continuum of 2D hexagonal lattices. The collisions generate vortices located at the corners of the lattice. The vortices release equal amounts of randomized gravitational and electromagnetic energies of anti-symmetrical and symmetrical modes of the double-helical structures, respectively. Among this continuum of lattices, there is a discrete set of special lattices in which the randomized free energy is able to be condensed into the lattice structure with a perimeter of critical length in which occurs full resonant exchange between free kinetic and potential components of gravitational and electromagnetic energies. Such special lattices are energy attractors and store the major portion of the total energy of the entire structured universe. The vacuum is the last (and of the largest spatial scale) among these lattices terminating the process of energy structuring in the form of *continuous lattices*, and the remnant free energy is condensed to *discrete physical objects*, and particles.

Geometry of elementary cell in 3D vacuum lattice

Eventually, an unperturbed vacuum lattice is a composition of identical elementary cells composed of double-helical flows with hexagonal shapes (see Fig. 3 below). The hexagon shape is the result of a dense package of identical double-helical tori. Longitudinal and transverse velocities of poloidal and toroidal rotations are each equal to the light velocity *c*. It is easy to come to this conclusion since the velocity of photonic (purely electromagnetic) excitation is known to us from experiments. Remember that photons are just phase modulation of the Planck-frequency carrier propagating along the vacuum cells with this velocity. The transverse velocity of poloidal rotation has the same value, and the total superfluid velocity equals to $c\sqrt{2}$.
Without going into lengthy explanatory descriptions, we just bring here the image of an elementary block of the vacuum lattice.

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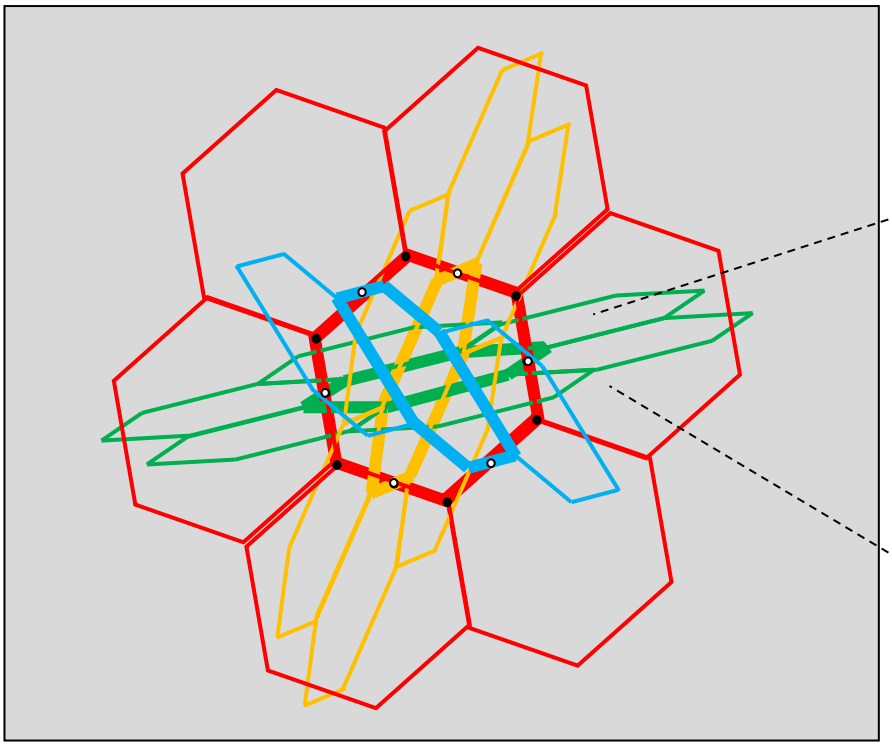

Fig. 3. Illustration of the vacuum lattice structure geometry, filling the 3D space with four sets of planar honeycomb lattices with a relative orientation of 120°. All hexagonal contours are produced by double-helices of the superfluid flows. Perimeters of elementary hexagons tiling the vacuum lattice are known as Planck's length, and equal to $\lambda_P = 1.616 \times 10^{-35} m$.

A close view of the hexagon's corner points (black points in Fig. 3) reveal vortices enabling nonlinear energy transformations of gravity to electromagnetism and vice versa, as well as energy translation between a variety of spatiotemporal scales. Small white circles mark 90° interception sites of double-helical streams, where occur bidirectional linear transformations between kinetic (magnetic) and potential (electric) types of electromagnetic energies. This type of transformation is responsible for the well-known Faraday induction phenomenon and provides a mechanism for the propagation of electromagnetic fields in space. The same site provides a similar mechanism of gravitational energy standing behind gravity waves.

In the geometrical model shown in Fig. 3, the cells' perimeter equals the Planck length. It is a 3D structure composed of straight sections with vortices in the lattice corners. Straight sections of this lattice are double-helical superfluid flows. The cell length is adjusted to prove the full exchange of two kinds: (a) between equal amounts of kinetic gravity energy and potential electromagnetic energy, and (b) between equal amounts of potential gravity energy and kinetic part of electromagnetic energy. The Vacuum Lattice enables the utmost dense energy package with an optimally minimal amount of free energy. It is composed of totally four sets of 2D lattices, intercepting at angles of 120°. 2D lattices of each set are parallel-oriented. The interception is a topological constraint, leading to inevitable interceptions and collisions of double-helical flows, and is the energetic source of vortex sites. The vortices operate as generators of equal amounts of free energy of both symmetric (electromagnetic) and anti-symmetric (gravity) propagation modes. A continuous spectrum of free energy released by vortices is then condensed back inside the vacuum lattice, which is an efficient energy attractor. This energy replenishes the energy lost by the vacuum lattice and feeds the discrete spectrum of phononic excitations supported by the vacuum lattice.

Fig. 4 summarizes the concept of the vacuum lattice and its excitations. Plate (A) roughly describes the hierarchy of the matter organization in the universe. Plate (B) shows only one helical flow as an elementary brick of the matter organization. The matter organization is fractal and multi-scale, whereas the helix belonging to each larger scale is composed of smaller-scale helices with the same shape. The total stored in its energy equals the energy of an inert superfluid substance moving with the velocity $c\sqrt{2}$.

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Each lattice releases some amount of free energy, which may be considered as its “losses“. These losses are consumed by other lattices and in particular by special discrete lattices supporting spatial resonances. As a result, these special lattices accumulate the dominant portion of the overall energy. As a whole, the entire plurality of lattices and discrete particles is a lossless conservative entity, as required for the system’s compliance with the energy conservation principle.

For detectable by us, part of this hierarchal system composed of isolated physical objects, the Vacuum Lattice, is the creative factor and the prime energy source. In other words, decay (e.g., local partial destruction) of the lower-scale matter organization, the vacuum, gives birth to the realm of larger-scale and much more creative higher-order scales of spatiotemporal organization and geometrical structures. The diversity of these disparate objects and their agglomerates constitutes for us the detectable part of the universe and has been the subject of physics study until now.

Starting with the vacuum lattice, each physical object of the higher-level organization, e.g., an elementary particle or complex system, is stable if it supports energy exchange between optimally balanced amounts of kinetic and potential energies. All other objects lose fast their inner energy and experience fast decay. Among elementary particles, the most stable are those in which structure takes place spatial resonance between free gravity and electromagnetic energies released by different scales within these same structures. Such particles are energetically nearly self-sufficient since they consume their own lost energy. They constitute a discrete spectrum of spatiotemporal levels. De Broglie wavelength spectrum of these macroscopic objects occupies the range $[\lambda_P, \infty]$.

Part of this chain process of the matter self-organization is illustrated in the following flow chart. Remarkably, large gaps on the wavelength axis between these most stable discrete levels of the matter organization are nearly empty, i.e., not populated by stable objects. Among spatiotemporal scales of stable physical objects are: the vacuum lattice itself, quarks, nuclides, electrons, atoms and their agglomerates, photons, biological molecules, living systems, and objects of cosmic scales. Cosmic scales occupy a special place in the hierarchy of matter organization and have their own multiple-scale architecture. All together all multiple spatiotemporal scales of the matter organization form the universe. The described universal structure has all features of a single vortex in which all spatial scales are interrelated by inner energy exchange mechanisms in the course of the universe’s perpetual dynamical evolution.

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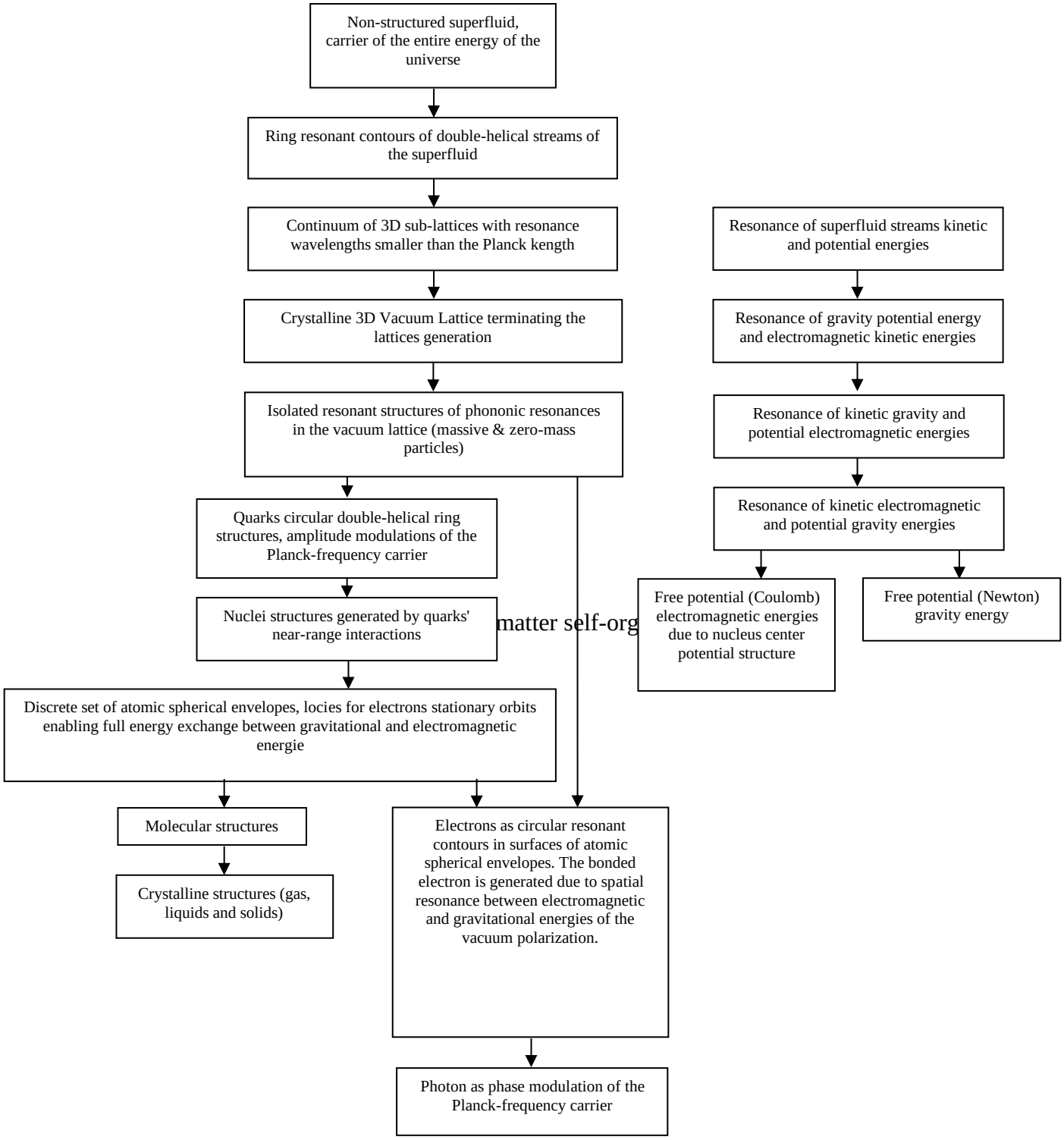

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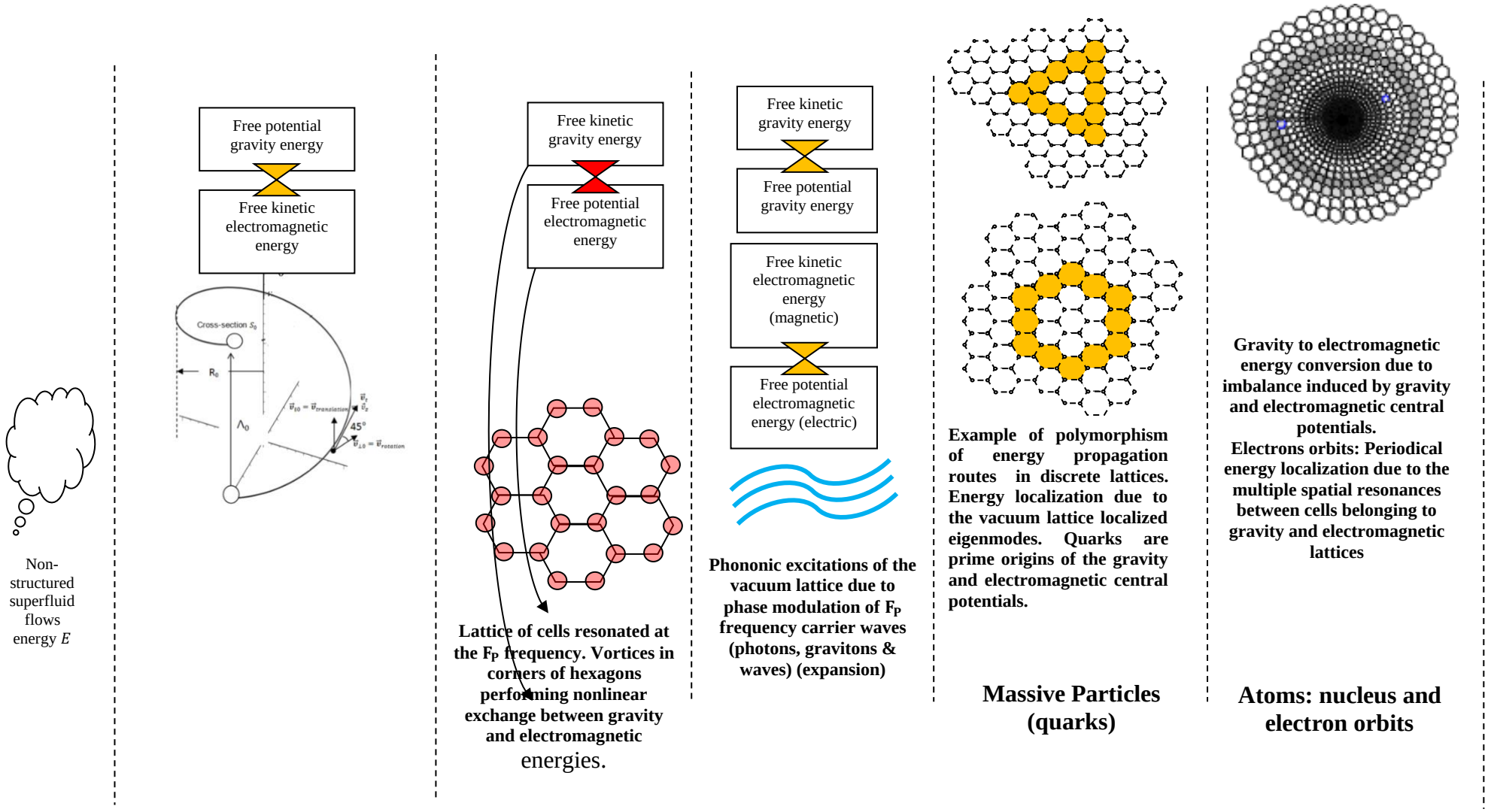

Fig.4 Evolution chain of the superfluid streamline flow metamorphosis

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The vacuum lattice is the main energy storage and is a source of energy generating all its phononic excitations, and elementary particles. The particles and their agglomerates comprise our detectable physical reality. The vacuum lattice provides two basic mechanisms of energy transformation which are the inner mechanisms standing behind laws and equations of modern physics:

- bi-directional mutual conversion of kinetic and potential energies of symmetric (electromagnetic) excitations. Similarly, there is a similar mechanism of energy conversion for the anti-symmetric (gravitational) excitations. This transformation is accompanied by an inherent phase retardation effect for the energy carriers at the Planck frequency. This energy conversion is a linear bidirectional mutual transformation of longitudinal and transverse velocity components of the superfluid streams intercepting at the 90° angle (see Fig. 3 above). Such interception does not break the double-helical flow symmetry and does not yield an exchange between symmetric (electromagnetic energy) and anti-symmetric (gravitational energy) propagation modes in double-helices. Photon is an example of a purely electromagnetic particle generated by the resonant exchange of equal amounts of electric and magnetic energies. Maxwell's macroscopic equations of classical electrodynamics describe the collective behavior of photons forming the electromagnetic wave phenomenon. The waves are composed of a large number of photons whose helical structures are oriented strictly in parallel to each other, and moving along the lattice in the same direction. The wave collective of photons is glued by the energy of the photon's $\gamma - \gamma$ mutual interaction;
- nonlinear process of bidirectional conversion of gravity energy of anti-symmetrical velocity component in double-helical superfluid streams to equal amount of electromagnetic energy of symmetrical velocity component. This energy conversion effect is the origin of both inertial (kinetic energy) and gravity (potential energy) masses, electric charge, and magnetic moment in quarks. Such processes take place in structures of curved double-helices, e.g., quarks, which have a circular ring shape. Quarks are vacuum lattice excitations generated by the mechanism of amplitude modulations of the streamline velocity carrying oscillations at Planck's frequency. These resonant waves of the vacuum lattice are energy carriers of all excitations, including photons (phase modulation of the Planck frequency wave) and quarks (their amplitude modulation).

The kinetic energy format is employed in the lattice for energy redistribution along its structure, while the potential energy modality performs the function of the excitation energy local confinement or depletion. The areas of energy accumulation and depletion are traditionally macroscopically described as positive and negative, respectively, masses, electrical charges, and magnetic moments. These objects may be viewed as positive and negative solitons. Gravity and electromagnetic energies are carried by antisymmetric and symmetric constituents, respectively, of superfluid flows. The flow decomposition to symmetrical and anti-symmetrical modes may be beneficial for the analysis of solitons in hydrodynamics.

In modern physics, the concept of the matter fractal spatiotemporal organization is generally appreciated. However, the rationale for this remarkable phenomenon is still under exploration and is disputed. One of the open questions is why some of the frequency bands are densely populated, while others are depleted of energy density? Traditionally, the discussion relates to physical objects detectable in our experiments. In contrast, we shall try to contribute to this discussion, starting with the undetectable inner structure of the physical vacuum itself and underlying its more dense matter structure at frequencies above the Planck frequency. Hypothetically, there may be lattices similar to vacuum structure but of more subtly spatial scales and possessing any resonance frequency of their elementary cells. In this lattice hierarchy,

each next larger-scale lattice is generated due to randomized energy released by the neighbor smaller-scale and larger-scale lattices. Lattice generation is a natural response of the superfluid medium when it is being charged by some amount of free energy. For example, the phenomenon of the Abrikosov vortex lattice was observed in superconductive media exposed to the free energy of an external static magnetic field. The vacuum lattice exhausts the last universe resource for the generation of such lattices and culminates this process. The generation of discrete particles is a special role played by the Planck-frequency vacuum lattice.

At the same time, it should be taken into account that resonant objects of a smaller scale are the building material for large-scale objects. At the same time, large-scale resonant objects are generated due to losses emitted from these small-scale building blocks. This rule is graphically illustrated by the following Fig. 5.

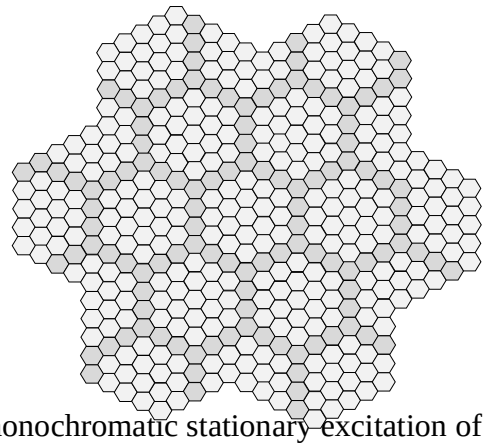

Fig. 5. Energy distribution of monochromatic stationary excitation of the wavelength $\lambda_{excitation}$ of a two-dimensional vacuum lattice structure with wavelength λ_{PL}. The excitation frequency is much lower than the Planck frequency. The excitation energy concentrates exclusively along resonant contours. Each cell of the Planck (vacuum) lattice contributes to the exchange between kinetic and potential energies of the excitation. The shown spatial distribution of the excitation energy along resonant contours is stable when an integer number of complete transformations of the excitation energy from kinetic to potential and backward takes place during its circulation along a closed resonant loop. For small $\frac{\lambda_{excitation}}{\lambda_{PL}}$ the resonant contours are hexagons, whereas for sufficiently large values of $\frac{\lambda_{excitation}}{\lambda_{PL}}$ the contour shape becomes circular.

As will be discussed later, the energy connection between the various space-time levels of the matter organization is direct. This internal dialectical conflict between the condensation of one structure at the expense of the destruction of a structure of another order of magnitude is the key to the perpetuity of the universe, if we exclude, of course, the possibility of the universe's destruction under the influence of external factors.

In addition, mutual and complete energy exchange can take place between the distributed kinetic energy densities of the symmetric and anti-symmetric excitation components of double helixes comprising the vacuum lattice. The existence of such properties of matter as gravitational and inertial masses, electric charge, and magnetic moment is a direct consequence of this conflict, which results in the formation of sections in the structure of a massive particle with unbalanced densities of gravitational and inertial gravitational energy or unbalanced density of electric and magnetic energy. Thanks to this phenomenon, our physical reality is so diverse and rich in events.

The above observation is in line with the fractal universe structure in which large-scale objects are composed of small-scale objects and are fed by random energy (actually, losses) released by these small-scale structures. By the way, the confinement of gravitational energy in a tiny area between two helices explains the experimental fact that electromagnetic excitation is perceived as a much stronger force, than the gravity excitation appearing in our experiments as a much weaker force. Historically, this led to the fast development of electromagnetic technologies and the inability of mankind to put their hands on gravitational energy.

So, in principle, a continuum of vortex lattices may be generated for any resonant wavelengths below and above the resonance wavelength of the vacuum lattice equal to the Planck length. But there is a discrete set of *special wavelengths* for which the corresponding lattice performs bidirectional conversion of *equal amounts* of gravity and electromagnetic energies. Such special lattices are the most stable among the continuum of lattices since in their structure takes place mutual compensation of free kinetic/potential energies of gravity by equal amounts of potential/kinetic free energies of electromagnetic modality. Actually, this means that these lattices support two resonant processes due to full bidirectional energy exchange between:

a) kinetic substituent of gravitational energy (manifesting itself as energy stored in inert mass) and potential electromagnetic energy (known to us from phenomena of electric charges and electric component of the electromagnetic field);
b) potential gravitational energy (energy of gravity mass appearing as a coefficient in Newton's law of gravity) and kinetic electromagnetic energy (energy stored in magnetic moment and magnetic field).

Due to their enhanced ability to reduce free energy due to gravity-electromagnetic resonance in their structures, these lattices are perfect energy attractors. Lattices belonging to this discrete set feature much greater density of their total energy in their structures. The vacuum lattice is the last in this set, possessing the largest resonance wavelength λ_P equal to Planck's length. Above λ_P the remnant universe energy is exhausted and is not sufficient to fill the entire space with resonant objects exchanging gravity and electromagnetic free energies. In the wavelength Fourier spectrum, it occupies a boundary position between the continuum of lattices $[0, \lambda_P]$ and resonant wavelengths of inner oscillations of isolated physical objects observable by us, which occupy the $[\lambda_P, \infty]$ band. Among these physical objects are zero-mass gravity & electromagnetic waves and massive particles, starting with quarks. The massive particles fulfill the same mission of gravity/electromagnetic resonance, albeit to a lesser extent, and are spatially isolated from each other in their inability to for next-order lattice.

Gravity-electromagnetic resonances belong to the class of spatial resonances. In spatial resonance, unlike frequency resonance, full exchange between kinetic and potential energies occurs due to the fact that it may happen between oscillations at two different frequencies in closed-loop structures of *special critical length*. This description may evoke the complete exchange of energies between symmetric and anti-symmetric propagation modes in a transmission line composed of two identical parallel-oriented dielectric waveguides, e.g., the line composed of two parallel identical dielectric rods. Such transmission line is able to propagate electromagnetic waves of symmetric and anti-symmetric modes. In order to establish the effect of spatial resonance, fields' distributions of both propagation modes in the transmission line cross-section must overlap. In the case of two dielectric rods, the modes coupling mechanism is due to the non-homogeneity of its cross-section, while in the case of hydrodynamic double-helical flows the coupling is achieved by bending the sufficiently long double-helix to torus. This breaks the transmission line symmetry and brings radiation losses, but is able to establish coupling between anti-symmetric and symmetric propagation modes.

The double-helical torus geometry appears to be common for all quantum-mechanical objects possessing mass. In contrast, the photon and particles responsible for gravity waves have straight helical geometry, and energy exchange between gravitational and electromagnetic energies in their structures is impossible. Possibly, besides the fact that the anti-symmetric propagation mode (gravity) is much closer to interaction with the outer world than the symmetrical mode (electromagnetic), this is a reasonable explanation for difficulties to detect gravitational waves.

Lattice generation by condensation of randomized energy proves to be the optimal way to reduce the system's free energy regardless of what frequency of excitation we are talking about. In each generated lattice with arbitrary self-resonance frequency, neighbor cells are tightly energetically coupled, and the resonant frequency of its elementary cells is the upper frequency of the conduction band for its monochromatic electromagnetic excitations. This fact predicts the inability to propagate electromagnetic waves in a vacuum lattice above the Planck frequency. Moreover, the theory of 2D lattices [8, 9] composed of tightly coupled coherent resonant loops reveals that harmonic excitations at frequencies occupying the range in close proximity and below the lattice band-edge frequency propagate along straight beams coinciding with the lattice axes of symmetry. In 3D lattices, monochromatic excitation propagates along helical trajectories with equal longitudinal and transverse velocities. In the vacuum lattice, the longitudinal velocity of photonic excitation is known as the light velocity.

In agreement with the results of the double-slit experiment with electrons diffraction (Davisson and Germer, 1927), the curvilinear geometry of elementary particles serve as the basis for De Broglie's hypothesis on the possibility of describing elementary particles as oscillators with a single resonant frequency. Now, considering the behavior of vacuum phononic excitations at frequencies close to the upper frequency of its conduction band, we are able to explain why all elementary quantum objects of our three-dimensional world have only one resonant frequency. Taking into account that in our model elementary particles have structures with distributed geometry, this means that this should be one-dimensional curvilinear geometry. These conclusions support the initial provisions underlying the String Theory. Please note that the newly introduced $T(q,\dot{q},t)$, $U(q,\dot{q},t)$ and $L(q,\dot{q},t)$ are all per-unit-length energy densities, and have dimensions of $[Joule/m]$. Correspondingly, the global energies of these objects should be calculated as contour integrals. Equations (4) and (5) may be interpreted as statements that the Lagrange function $\mathcal{L}(q,\dot{q},t)$ and the free energy density $L(q,\dot{q},t)$ are the global and local imbalances, respectively, between amounts of kinetic and potential energies within the entire volume occupied by the particle or the system.

The free energy distributed along the structures of elementary particles governs the local dynamical evolution of energy components within the particles' structures, and in the case of elementary particles, with the exception of low-frequency photons, is not detectable in our large-scale experiments. Probably, this is the reason why these inner oscillations within "elementary" particles were neglected in the past, although the wave nature of quantum-level objects was the main premise of quantum mechanics.

The free energy unevenly distributed along the particle governs the *local* dynamical evolution of energy components within the particle's structure, and in the case of elementary particles is not detectable in our large-scale experiments.

Following is a brief summary describing the superfluid flow evolution culminated by the creation of the ordered fractal multiple-scale vacuum structure. This issue was already discussed above, and this is just a reminder. As any time-dependent function, energy functions $T(q,\dot{q},t)$, $U(q,\dot{q},t)$ and $L(q,\dot{q},t)$ may be decomposed to Fourier integrals of their spectral densities. At each given frequency, an attempt to

minimize the local density of free energy leads to the generation of closed-loop structures along which the total amount of free energy stored in resonant oscillations, is minimal, i.e., integrals of kinetic and potential energies along the closed loop are optimally balanced. As a result, at any arbitrary frequency, the energy of the universe is conserved in oscillations of high-quality identical closed-loop resonant objects. Isolated resonant objects have circular shapes, but when in an attempt to store the energy with optimally high density, they are reshaped comprising sub-lattice with hexagonal symmetry. Physical vacuum is one of such lattices and is also composed of densely packed elementary cells of hexagonal shape with perimeters equal to the Planck length, supporting harmonic oscillations at Planck resonance frequency. The Planck lattice occupies an exceptional place in the entire hierarchy of sub-lattices, and provides a mechanism for all large-scale energy transformations. This means that the vacuum lattice literally generates particles and waves by means of its built-in mechanisms of bidirectional conversion of kinetic and potential energy. The results of these energy transformations are briefly illustrated in the next paragraph.

10. Elementary particles as a vacuum lattice excitations

By definition, any kind of superfluid substance flow deviation from the ideal Beltrami helical shape will be called the structure *excitation*.

All elementary particles are generated as the system attempt to achieve its maximum quality factor by condensing the free randomized energy remaining after the vacuum lattice formation to resonant structures. Particles may be viewed as phononic excitation (or modulation) of the vacuum crystalline structure. The particle dimensions are typically more than 20 orders of magnitude larger than the Planck length, and the energy density of the phononic excitation is much smaller than in elementary cells of the vacuum lattice. Hence the modulation produced by the particle on the vacuum lattice is a very low De Broglie frequency compared with the Planck frequency. In other words, the modulation sidebands are very close to the Planck frequency and occupy the frequency range just below the upper edge of the vacuum lattice stopband. It is known that such excitations propagate along two-dimensional curvilinear trajectories [11-12], and may be addressed as “strings“. The one-dimensional strings are generated at the Planck scale of the vacuum lattice, whereas the elementary particle is also the string-like curvilinear object of a much larger scale, but is composed of a large number of energetically coupled strings of the Planck scale. In future discussions of large-scale processes, this fine structure may be neglected, and the particle structure may be approximated by a single string of finite thickness. The massive particle has the shape of a toroidal double-helical resonator produced by curved to the circle double-helix, whereas the photon is shaped as a straight helical string propagating along the vacuum lattice with right-hand or left-hand spin rotation.

Along the curvilinear structure of the massive particle, the phononic modulation of the vacuum cells is performed steadily, and complete transformation from gravitational kinetic (potential) energy to electromagnetic potential (kinetic) energy is achieved along the chain of transformations in the propagation path composed of a very large number of the Planck level cells. Each Planck cell contributes only a small portion to the common energy conversion process.

Particles are initially isolated from other resonant objects but are capable of agglomeration, if this operation leads to the generation of a new complex particle with an enhanced quality factor.

Massive particles

The elementary massive particle is a confined circular ring phononic excitation of the vacuum lattice. Actually, the excitation structure is produced by the resonant wavelike process propagating along the circular contour, resembling a typical ring resonator. The ring structure is composed of two oppositely directed helical superfluid streamlines curved to a torus. Relatively the vacuum lattice elementary cell the smallest massive particle is a large-scale structure with dimensions greater than the vacuum cell size by an order of 10^{20} or more.

The massive particle excitation is produced by a process of spatial resonance. There are two optional ways of spatial resonances generation:

Option A: Kinetic energy belongs to symmetrical, i.e., electromagnetic vacuum lattice excitation, while the potential energy belongs to anti-symmetrical, gravity excitation;

Option B: Kinetic energy belongs to anti-symmetrical, i.e., inertness type of excitation, while the potential energy belongs to symmetrical, electromagnetic excitation.

In both cases, the single transformation from kinetic to potential energy and backward transformation from potential to kinetic energy takes place along the helical torus perimeter. It is sufficient to analyze one of these options in order to comprehend the rational standing behind the massive particle generation. According to Option A, the transmission line process in which the kinetic energy density of electromagnetic excitation (i.e., the magnetic energy) is converted to the potential energy density of gravitational energy. The massive particle is the result of energy coupling between two propagation modes supported by double-helical transmission lines belonging to the same torus. The question may be asked on whether the symmetric and anti-symmetric wave modes propagate along double-helices of the same spatial scale. As will be seen from the following discussion, the answer is negative. The electromagnetic excitation belongs to the large-scale structure, whereas the gravitational part of the excitation propagates along the smaller-scale structure!

Here we have to provide an explanation of the fractal feature of toroidal structures. Our explanation is related to the necessity to explain the superfluid behavior in its strive to produce the particle's structures possessing the optimally large quality factor.

The most powerful way to achieve this goal is to generate multi-scale fractal structures in the superfluid flows, which we shall call further *fractal curved double-helical streams*. The goal is achieved by breaking each helical stream of any spatial scale $(n+1)$ to the finer double-helical structure of smaller scale n. As a result, any double-helix becomes composed of building elements of the same shape as the whole double-helical structure. Generation of the fine-scale structures by superfluid streams is a brilliant method leading to much higher energy density and energy storage with a much higher quality factor. We have to recall that double-helices of different scales of this fractal are phononic excitations of the vacuum lattice. As always in phononic excitations, the energy of resonant structure of scale n is in inverse proportion to wavelength λ_n. This means that the energy of small-scale helices is greater than the energy of the larger scale by the ratio $\frac{\lambda_{n+1}}{\lambda_n}$. In addition, the ratio of volumes occupied by the double-helical resonant structures of the n-th and the $(n+1)$-th scales is $\left(\frac{\lambda_{n+1}}{\lambda_n}\right)^3$. Hence the ratio of energy densities in these scales is proportional to $\left(\frac{\lambda_{n+1}}{\lambda_n}\right)^4$. The total losses of fractal structures are also reduced since losses generated by small-scale resonant objects are utilized for the generation of resonant structures of a larger scale. Experimental results reported in [10] are in line with the above observations.

We have to add several words on the mechanism of coupling between symmetric and anti-symmetric propagation modes in double-helical structures. In the straight double-helical absolutely balanced transmission line these modes are orthogonal, but in a circular ring produced by a curved double-helix, these modes are coupled, and their interaction may be described by the equations of the coupled mode theory [11]. In integrated optics, the coupling mode theory is applied to two electromagnetic modes propagating within the structure composed of two parallel dielectric waveguides. In this case, both coupled modes are due to harmonic oscillations tuned to the same frequency, and the coupling mechanism between two waves propagating in these each waveguide is due to the difference of effective dielectric constant experienced by symmetric and anti-symmetric modes supported by this heterogeneous structure. In the case of a curved double-helical structure the surrounding medium is homogenous, but coupling between symmetric and anti-symmetric propagation modes is due to the

mechanism of partial energy conversion *inside* the streams themselves. The mode's coupling is due to the slightly asymmetrical structure of the double helices. The coupling coefficient in this case is proportional to the r/R ratio, where r is the cross-section radius of the double-helical stream, and R is the radius of the stream curvature.
In each spatial scale of the fractal curved double-helical streams there are two coupling mechanisms between the symmetric and anti-symmetric modes:

a) due to the asymmetry of the superfluid streams belonging to the same spatial scale;
b) due to the asymmetry of the superfluid streams belonging to the next finer spatial scale.

For an explanation of the coupling phenomenon, it is worth noting that the symmetric and antisymmetric modes produce different effects on collocated physical objects. Any interaction between the neighbor objects is due to mechanisms of excitation propagation in the vacuum lattice. The impact of excitations, i.e., of the anti-symmetric (gravitational) mode, is very weak since the excitation streams are oppositely directed and the impacts of each stream within the double-helical pair are actively canceled by the oppositely directed stream. Hence, the impact is confined mostly in the inner volume between two helices. In contrast, the impacts of both members comprising the symmetric excitation mode are summed in phase and freely propagate in the outer space of the vacuum lattice. In summary, the gravitational propagating mode is reluctant to interact with the outer world, and generates very weak interaction effects. In contrast, electromagnetic energy is open for interactions with collocated particles. This explains the easiness of its detection and generation and the fact that the electromagnetic phenomena gave birth to numerous practical applications, whereas the gravity phenomena are practically not explored.
Both coupling mechanisms are built into the volume of superfluid streams, although in mechanism (a) symmetric and anti-symmetric flow components are of the same spatial scale, while in the case of mechanism (b) they belong to different spatial scales. In both cases, the problem of physical misalignment between the symmetric and anti-symmetric components of the streams does not exist.
The qualitative analysis brings us to the conclusion that the mode conversion is more efficient when symmetric and antisymmetric modes belong to different scales. The excitation energy of the smaller-scale helix is efficient exactly inside the stream of the large-scale helix, while the excitation of the larger-scale antisymmetric mode is confined mostly within the volume without the superfluid excitation.
Excitations of small-scale double-helices carry oscillations of much higher frequency than the larger-scale excitation. Higher frequency double-helical structures of the superfluid flows are generated by wave processes with greater wavenumber. Actually, this means that the anti-symmetrical wave is supported by double-helices with a proportionally smaller pitch. As a result, we may conclude on the complete geometry of the elementary massive particle:

- The double helix comprising the particle is curled into a kind of ring resonator tuned to the particle De Broglie frequency;
- Each helix comprising the double-helix of the particle ring structure is itself a finer-scale double helical structure supporting the oscillation of gravitational waves of much higher frequency and possessing much higher energy than the electromagnetic (symmetrical) mode;
- The interaction between symmetric and antisymmetric modes, i.e., between energies of electromagnetic and gravitational modalities, may be viewed as an energy exchange between oscillations supported by double-helical structures of different spatiotemporal scales. Our experiments are able to detect energies belonging to structures possessing an imbalance of four possible modalities:
    a) Kinetic energy of gravitational excitation, which in our experiments appears as inert mass;
    b) Potential energy of gravitational excitation, which gives birth to gravity mass;
    c) Kinetic energy of electromagnetic excitation, which manifests itself as magnetic moment;
    d) Potential energy of electromagnetic excitation, i.e., electric charge.

The interaction energy generating such phenomena as inert and gravity masses, electric charge, and magnetic moment are relatively small in comparison with the dominant energy of the anti-symmetrical (gravity) mode supported by fine-scale double-helices. Probably, the rest dominant energy which is not detectable by our instruments is the so-called "dark energy".

The mass generation

The excitation generated by the mechanism of coupling between the potential energy of the larger-scale antisymmetric mode and the kinetic energy of the smaller-scale symmetric mode may be described by energy density functions

$T(\dot{s},t) = \frac{1}{2}\rho_0\left[v_{\parallel}^{s}(s,t)\right]^2$, and

$U(s,t) = \frac{1}{2}\rho_0[v_{\perp}^{a}(s,t)]^2$.

In the above expressions the terms

$v_{\parallel}^{s} = c[1 + sin(\omega t - ks)]$, and

$v_{\perp}^{a} = c[1 + cos(\omega t - ks)]$, where $\omega = 2\pi f$ and $k = \frac{2\pi f}{c}$

, are longitudinal and transverse components, respectively, of the superfluid velocity of vacuum cells involved in the generation of massive particles.

Substitution of velocity expression to energy density formulas yields

$T(\dot{s},t) = \frac{1}{2}\rho_0 c^2[1 + 2sin(\omega t - ks) + sin^2(\omega t - ks)]$, and

$U(s,t) = \frac{1}{2}\rho_0 c^2[1 + 2cos(\omega t - ks) + cos^2(\omega t - ks)]$.

Hence the total energy density in the excited resonant contour is:

$$E(s,\dot{s},t) = T(\dot{s},t) + U(s,t)$$
$$= \rho_0 c^2\left[1 + 2\left(sin(\omega t - ks)\right) + cos(\omega t - ks)) + sin^2(\omega t - ks) + cos^2(\omega t - ks)\right] =$$
$$= \rho_0 c^2\left[2 + 2\left(sin(\omega t - ks)\right) + cos(\omega t - ks))\right].$$

Integration of the energy density along the entire resonant contour with length ℓ yields

$\mathcal{E}_{TOT} = \int_C [T(\dot{s},t) + U(s,t)]ds = 2\rho_0 c^2\,\ell = 2\mathcal{E}_{TOT,0}$.

As can be seen, like any amplitude modulation, makes necessary energy investment for the generation of the massive particle excitation. The expression (TBD) shows that the total energy density averaged along the entire particle's structure is twice larger than the same energy $\mathcal{E}_{TOT,0}$ in the unperturbed vacuum. The massive particle is able to bond the energy belonging to the universe into the confined resonant structure featuring greater energy density than it may be done by the unperturbed vacuum. This is the basic motivation of the entire universe to generate elementary massive particles.

Quarks

The original shape of an isolated massive object is a toroidal double-helix. The most elementary massive object is a quark. Quark realizes the possibility of a spatial resonance between the energy of electromagnetic excitation of the space-time Planck level and gravitational excitation of a much smaller scale. This spatial resonance process gives rise to such phenomena as gravitational mass, inertial mass (or simply inertia), electric charge, and magnetic moment.

The massive particle is generated as the amplitude modulation of the vacuum lattice, and its generation needs either energy investment in the vacuum lattice (positive mass generation), or its depletion (negative mass generation). Negative mass means the generation of an object as a result of energy depletion in a confined area of the vacuum lattice. The negative mass generation is a very rare event since the universe is the place for storage of the *positive* excessive energy, and areas featuring depleted vacuum energy are singular exceptions.

There are three possible basic *isolated* quark conformations, in accordance with three types of spatial resonances that may be generated in the vacuum lattice:

a) Types A and B, as described in the Para. 10 above, and

b) a combination of Option A and B within the same structure.

The above options enable the realization of structures along which occurs a single back-and-forth transformation of electromagnetic and gravitational energy. These structures have poles confining uncompensated free energies of four types listed above in Para.15. They have half-integer spins, which means that these particles are fermions. Similarly, to particles with energy density exceeding that of unperturbed vacuum lattice, i.e., positive energy density, there is an option of phononic anti-particles featuring depleted energy densities. Structures possessing positive and negative energies are generated due to the nonlinear effect of transformation between the gravitational and electromagnetic energies, and may be classified as positive and negative solitons. Negative solitons occupy areas confining negative gravity and inert masses.

We have to distinguish between the particle with a negative mass and the anti-particle. The negative mass particle is generated in the vacuum lattice areas with depleted energy, but the helical rotations in its structure are still right-hand, and they belong to the category of Matter particles. On the contrary, anti-particles are generated in the universe areas where the Planck-scale structure is composed of double-helices with left-hand rotation. The energy of the anti-particle is still positive if the energy density in its structure exceeds the energy density in the unperturbed vacuum. Anti-particles may be generated in the vacuum lattice areas with the right-hand double-helical rotation. For this, it is sufficient to produce some action that inverts the rotation direction in the transverse plane of its structure. The anti-matter particles easily annihilate with the matter particles, and are not stable in the universe areas with the right-handed vacuum lattice.

It is anticipated that quark particles with negative inert and gravity masses possess also negative electric charge and negative magnetic moment. Particles with higher-order resonances supported by their ring structures are also a theoretical option.

We shall not speculate on what exactly confirmation or option suits the traditional classification of these important particles, since such classification requires comprehensive qualitative analysis and should be verified by experiments. Nevertheless, calculations of quality factors may provide information on their stability (lifetime).

The process of quarks generation enables long-term confinement and storage of energy which remains excessive after the vacuum lattice condensation. Quarks may be dynamically generated as a result of collision events in the universe. But they are not observed in experiments as isolated particles since there is a better option to employ them as building blocks for much more stable structures like protons and neutrons. Probably, a proton is a unique stand-alone structure featuring the highest possible value of the quality factor, which makes it practically immortal. Neutron agglomerate gains exclusively long lifetime only due to its agglomeration with a proton.

Particle agglomeration is a very effective method of energy confinement and long-term storage. The agglomeration produces two effects, both enhancing the quality factor: generation of vortices and simultaneous reduction of boundaries through which the agglomerate may lose its inner energy. The observed experiments on the physical reality provide us with an indication that the agglomeration of three quarks, i.e., of three double-helical circular rings, appears to be the most stable and long-living structure. Three agglomerated optimally shaped double-ring resonators feature (a) straightened common boundaries saving radiation losses, and (b) generation of four vortices. Vortices are effective and high-quality energy storage, a kind of bifurcation located at the point of the flow interception. The stored in the agglomerate energy is enriched by an additional contribution of near-field interaction between two neighboring double-helical rings. Modern physics identifies these energies as gluon particles responsible for the energy exchange, and the forces of quark-quark interaction as a special category of strong interaction possessing a special qualitative difference from other forces of gravitational and electromagnetic excitations. The structured vacuum theory does need an introduction of the new type of interaction. The strong nucleus and weak electromagnetic interaction forces are distinguished in our model as short-range (near-field) and long-range (far-field) effects generated by massive particle

structures. In the short-range interaction, two double-helical ring resonators form a common section with a quadruple cross-section. This interaction confines its energy in an inner volume, and is practically impervious to external influences and unbreakable. The same type of coupling exists between resonant hexagon contours of the vacuum lattice. Most of its power is stored in vortex sites linking massive particles with the vacuum lattice.

Atomic nucleus generation

Agglomeration of several quarks into an atomic nucleus aims to further improve the quality factor of the system. In this case, the vacuum structure surrounding the nucleus reacts by creating an electron. Proton and attached to it neutron form so successful combination in a sense of high-quality factor that it is used for building larger agglomerates. This operation is energetically beneficial and leads to the generation of a number of atomic structures.

The atomic structure features an additional feature enabling its better energy confinement and isolation from the surrounding world: electron generation. This measure shields the nucleus's positive electric charge and thus enhances its quality factor.

Generation of bonded electrons

The massive positively charged nucleus induces negative polarization of the surrounding vacuum lattice. The polarization is twofold: negative gravitational and negative electric. The polarization oscillates with the quark's De Broglie frequency. Negative polarization means that the potential energy (the transverse velocity component of the symmetric and antisymmetric modes) of each vacuum cell is below its normal level as in an unperturbed vacuum. A stable structure of a bonded electron arises as a circular resonance path along which the negative gravitational energy of the polarized vacuum lattice is converted back to an equal amount of negative electromagnetic energy. This gives birth to a negative electric charge and negative gravity mass. It appears that the bonded electron has a negative mass. As a result of the electron generation, a complete electrical neutralization of the atom takes place, but the gravitational polarization of the surrounding vacuum lattice remains uncompensated. This effect gives rise to the phenomenon of the static gravitational field of the nucleus.

Photon

Lastly, a photon is considered an effective means of direct transferring excitation energy over distances that are much larger than the atomic size. Unlike massive particles, photon excitation is a phonon in the form of phase modulation of the Planck frequency carrier propagating along the vacuum lattice. This means that the photon generation is not associated with additional energy investment, and its rest mass is zero. The free energy of a photon is in the *strictly directional nature* of its movement, and is taken into account by the linear and angular rotation momentum of its motion along the vacuum lattice.

The photon structure is helical (not double helical). The helix length along the axis of propagation equals its De Broglie wavelength λ_{PH}. The helix diameter equals to λ_{PH}/π.

The photon excitation may be decomposed to purely electromagnetic and equal amounts of gravitational counterpart. The photon electromagnetic effects are easily detectable due to the openness of the symmetrical electromagnetic excitations of the vacuum lattice. The antisymmetric photon's gravitational energy is less explored and is less recognized in modern physics, since it belongs to the anti-symmetrical motion of the superfluid, and its components cancel each other in most circumstances. Hence, the gravitational part of the photon excitation practically is not open for interactions with other physical objects. Nevertheless, it interacts with the vacuum lattice polarized by massive bodies. This explains photons deflection by concentrations of large stars and planets, as it also was predicted by Einstein's general relativity theory.

11. Conclusions

The paper describes the following major stages of the universe's genesis and makes it possible to reveal the relationship between the Matter, Space, and Time concepts:

- The initial state of the universe has a form of chaotic motion of the primordial superfluid **"Matter"**. The analysis assumes that the universe is a closed conservative system;
- Along all its evolution the universe performed and continues to perform the mission of the energy storage with the best possible efficiency. In order to accomplish this mission, the superfluid is self-structured to the non-detectable in our experiments the Planck-scale vacuum lattice which stores the dominant portion of the total universe energy.
- The vacuum lattice is the active medium giving birth to all known to us physical objects. For these objects, including us, the vacuum is what we are used to calling **"Space"**. **This means that the structured Matter generates the Space.** This is in contradiction with the commonly postulated hypothesis that the abstract empty space is an independent entity serving only as an arena for physical events. In the structured vacuum model, the vacuum is an *absolute reference system*, which means that the axiom of the relativity principle is not valid.
- The vacuum lattice supports its own phononic excitations in the form of elementary particles and their agglomerates. Particles are resonant structures with De Broglie resonance frequencies which are much lower than the Planck frequency.
- Phononic modulations of the vacuum lattice may be either amplitude (e.g., quarks), or phase (e.g., photons).

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