THE STANDARD MODEL AND THE THEORY OF EVERYTHING

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Abstract. This article discusses the advantages and disadvantages of the standard model of elementary particles, which underlies the modern quantum picture of the world. It is shown that facts that do not fit into the standard model continue to accumulate recently. These include divergences, contradictions that arise between the standard model and the general theory of relativity in the high-energy region and the impossibility associated with them to create a unified field theory, some cosmological problems, etc.

Keywords: symmetry, symmetry law, asymmetry, gauge fields, particles and the Higgs field, structuring, mass, particle and Higgs field, quantum gravity, theory of everything.

The modern (quantum) picture of the world is based on the standard model of elementary particles. Let's briefly review its content.

The world in which we live appears to us as a set of various, continuously changing and interacting discrete material bodies and physical fields. They form the material basis of the Universe. The physical field transfers interactions between bodies, which leads to a change in the order of mutual arrangement of the structural elements of bodies at different levels. It changes, in turn, the functioning of bodies. The main property of matter is its inertia, i.e. resistance to any change. The measure of inertia that causes counteraction is the mass m, and the measure of motion (coupling) is the energy value E Action, as you know, is always equal to counteraction, and energy is equivalent to mass ($E = mc^2$). Movement occurs under the influence of positive energy, and bonds are created by negative energy. All processes and phenomena caused by them are the result of mutual transformations of movement and connections.

For a long time, both matter and the field were considered continuous, continuous, and material formations, i.e. to physical bodies and their parts, local corpuscular properties were attributed, and to fields – opposite, wave properties. Accordingly, the processes of movement, the magnitude of energy and action were considered continuous. In quantum theory, it is established that matter and field, as well as the processes of motion and energy, have a discrete corpuscular-wave structure.

The substance of the highest, cosmic level, the so-called macrocosm, consists of all the diversity of things around us, incl. and ourselves. Its smallest structural elements are molecules. They form the atomic-molecular level of the microworld closest to us, located at a depth 10^{-10} m. A deeper (from 10^{-10} before 10^{-15} m) intra-atomic level is filled with electrons and atomic nuclei. The electrons are located outside the nucleus. However, they can also arise inside it, be absorbed or emitted by it in various intranuclear processes. The intranuclear level up to 10^{-18} m, as is currently believed, consists of two varieties of quarks (*u*, *d*), which form protons and neutrons in different combinations. Each of them also consists of three quarks, *uud* or *udd*. There is another, very small material particle, the neutrino, which is formed in intranuclear processes, but is not kept in the nucleus or outside it, but, having been born, is carried away at the speed of light into outer space.

Thus, all matter consists of four material particles, fermions, folded in certain orders, namely: two varieties of quarks (*u*, *d*) electron and neutrino. All changes occurring in the world around us are the result of the interactions of these fermions and their formations. They are carried by elementary particles of the corresponding fields, bosons.

All possible interactions of fermions are reduced to four fundamental interactions: gravitational, electromagnetic, strong and weak. Gravitational interactions exist between all fermions and are carried by hypothetical massless gravitons. Electromagnetic interactions bind electrons to the nuclei of atoms, atoms and molecules. They are also carried by massless photons. Strong interactions bind intranuclear particles – quarks, protons and neutrons and are carried by massless gluons and pi-mesons. Other subnuclear bosons (mesons) also participate in these interactions. Weak interactions transform one fermion into another and are carried by massive vector bosons, consisting of two different-valued particles *W* of increased but identical mass and one uncharged particle *Z* of even greater mass.

The intensity of interactions is characterized by the dimensionless coupling constant α_i, inherent in each of them, which is determined by the conserved charge and is calculated by the formula:

$$\alpha_i = \frac{k_i \cdot q_i^2}{\hbar \cdot c}, \tag{1}$$

where k_i – constant of the system of units of measurement (for electromagnetic interactions $k_i = 1/4\pi\varepsilon_0$ ($\varepsilon_0 = 8{,}85 \cdot 10^{-12}$ F·m^{-1}); for gravitational interactions $G = 6{,}67\ 10^{-11}$ m^3/kg s^2; for strong interactions – 1/4π; for weak interactions – $(\hbar/m_p c)^{-4}$ m^{-4}; q_i – generalized conserved charge; $\hbar$ – Planck's constant; c – speed of light in vacuum.

Fermions differ from bosons only in their symmetry and, accordingly, in their spin.

Fermions are described by a wave function with odd symmetry $[\psi(-x) = -\psi(x)]$. This means that they are subject to the Pauli prohibition, according to which no two interconnected identical real particles can be in the same state and, accordingly, in the same place.

Bosons, on the other hand, are described by a wave function with even symmetry $[\psi(-x) = \psi(x)]$. In other words, the Pauli exclusion principle does not apply to them.

The spin of the fermions of an atom is half-integer and is equal to 1/2, and bosons, with the exception of the hypothetical graviton, is integer and equals 1. The spin of gravitons is 2.

The half-integer spin of fermions, from my point of view, indicates that they have an internal, most likely, inhomogeneous structure, and a surface tension limiting them. In other words, fermions do not behave as a whole (changes in the internal environment lag behind changes in the peripheral shell formed by surface tension and are quantized in a ratio of 1:2).

Important characteristics of fermions are one or more conserved quantities, charges. Each of them is associated with energy flows – the momentum of a certain physical system (field).

Another important characteristic of the material world is physical symmetry.

It follows from Netter's theorem that symmetry imposes certain restrictions on the possible behavior of systems and, thereby, prevents their change and development. This means that it also eliminates order, which is known to be established by rules that violate equality and homogeneity, and stimulates the development of systems. On the contrary, the deviation from symmetry is a consequence of the spontaneously arising order of the mutual arrangement of the structural elements of the systems and the changes initiated by it.

At the same time, any order is extremely unstable, because its probability is infinitesimal compared to the probability of disorder. This, in other words, can be viewed as a fact of the indomitable striving of all material systems for disorder and symmetry. It is symmetry, most likely, that underlies the principle of quantum superposition and the universal principle of complementarity.

However, in real conditions the symmetry is broken. Otherwise, there would be no interactions in the Universe, and there would be no

Universe itself. The violation of symmetry and orderliness of the Universe, which ensure its stable functioning and development, is explained by the fact that the orders that determine the functionality of each system of the material aggregate of the Universe are reliably protected. The qualitative individuality of systems is ensured, in particular, by the corresponding fields and interactions operating at all their levels, as well as by surface tension that protects their internal orders, giving them the appropriate functionality.

The higher the level of organization of the system, the more complex and diverse its defense mechanisms in depth.

A low level of organization and protective mechanisms significantly slow down the processes of the material aggregate striving for disorder and symmetry, but they are not able to stop them. All symmetries realized in the world around us, for example, are approximate and, as a rule, are combined with asymmetry, i.e. spontaneous deviations from symmetry. This, in turn, is equivalent to the interaction of all material systems.

The birth of qualitatively new systems, from the Universe to man, always comes from single symmetrical and therefore stable, but not functioning elements, singularities, due to the violation of their symmetry. The subsequent division, structurization, ordering, and the rapid development of the singularity associated with it are the result of a chain of spontaneous symmetry breaking that follows one after another.

So, for example, according to the standard model and theory of the hot Gamow Universe, spontaneous symmetry breaking and structuring of the singularity of the Universe led to its decay into a large number of high-energy structural elements (big bang). As a result, a primary material bunch appeared, consisting, in accordance with charge symmetry, of an equal number of particles and antiparticles. Their violent annihilation, which began at the same time, was supposed to lead to the destruction of the clot and stop the further development of the Universe. But this did not happen. The catastrophe was prevented by a new symmetry breaking, which, presumably, was expressed in the fact that the transition of particles from a singularity to a bunch occurred somewhat faster than antiparticles. As a result, an asymmetry arose in the bunch in the form of an excess of particles, which led to the further formation and development of the Universe, etc.

It is also known that life is based on a protein molecule consisting of a long chain of amino acids. When synthesizing amino acids in laboratory conditions, in full accordance with the laws of symmetry, left and right twist helices appear in equal quantities. Such a protein, however, does not show any signs of life, although it is chemically completely identical to the protein of a living cell. The only difference between them is that the protein molecules of living organisms are asymmetric, since they consist of spirals of only one left twist. It is this asymmetry that enlivens them [4, 5].

Thus, any deviations from symmetry violate the homogeneity of the system and order it, initiating processes in it that seek to restore the broken symmetry, which manifest themselves as force fields. Stable functioning systems, like the Universe as a whole, are realized in reality only due to their deviations from symmetry. In this regard, the question arises, what is the source of symmetry breaking? After all, symmetric systems are not ordered and therefore stable. To answer this question, let us consider the laws of symmetry in more detail.

It is known that Netter's theorem is reversible. This means that a certain symmetry corresponds to each conserved physical quantity. To illustrate, consider, for example, the familiar electromagnetic field. Its source is, as is well known, a conserved electric charge. It follows that Maxwell's electromagnetic field equations must have a certain symmetry. Indeed, each of the observed components of the electromagnetic field (electrical and magnetic strengths) is determined by the corresponding gradient of the scalar potential or the curl of the vector potential. In other words, the transformations of these potentials, which are reduced to adding an arbitrary constant value to the scalar potential, and to the vector potential of some arbitrary function of coordinates, does not change the observed magnitudes of the strength of the electric and magnetic components of the field, and hence the field itself. The symmetry of the field, caused by the conserved value of the charge, which is also the source of the field, is called gauge. The fields themselves that obey this symmetry are called gauge fields. It turns out that all fields of fundamental interactions have gauge symmetry, i.e., electromagnetic, weak, strong and gravitational fields, and in this case we are talking about local gauge symmetry, which is not violated under different transformations at different points of space-time.

From a mathematical point of view, the invariance of physical systems in quantum mechanics under certain transformations, i.e. their symmetry follows from the definition of the wave function, which is the main characteristic of these systems.

Indeed, the ***wave function***, by definition, is a complex quantity

$$\psi(x, y, t) = \psi_1(x, y, z, t) + \mathrm{i}\ \psi_2(x, y, z, t). \qquad (2)$$

However, the observed values of the systems we are considering, although they are determined by the wave function, are at the same time ***real*** in their physical meaning. This means that nothing in the predictions of the theory will change if the wave functions are multiplied by a complex number equal in absolute value to one. In other words,

$$\psi \rightarrow e^{i\varphi}\,\psi, \tag{3}$$

where ψ is a complex wave function or a vector in the phase space of the real and imaginary components of this function; φ is an arbitrary number or phase of the above vector, the angle of rotation of the vector in the phase space.

Relation (3) is called the global gauge transformation. It reduces to the rotation of the complex vector ψ by the phase angle φ in the phase space of its components ψ_1 and ψ_2. When a vector is rotated by any angle, its length, i.e. its absolute value characterizing the system it describes does not change. In other words, quantum mechanics is invariant under global phase rotations (Fig. 1).

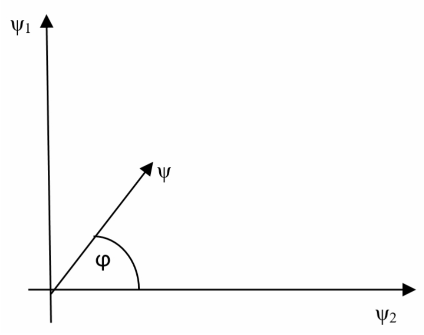

Fig. 1

It is obviously not invariant in the case of local gauge symmetry, for which the transformation, in our case, the rotation of the vector by an angle $\varphi(x, y, z, t)$, different at different points in space-time. In other words, the length of the wave function vector will change if it is rotated at one point by one angle, and at another point by another.

The rotation of the vector in this case is equivalent to the result of differentiation of the function expressing it, and when differentiating, additional terms arise that describe some additional vector field that violates the invariance of the original field. This field, however, can be compensated by introducing a new, additional, but equal field so that it also changes during rotation, but is opposite to the change in the vector field of the wave function and, therefore, restores its invariance, calibrates it . And this is not some kind of arbitrariness, not a mathematical trick, but exactly what Nature does, striving for symmetry.

Calculations show that the fields introduced by the above method correspond to real fields, which fully confirms the theory of gauge symmetry. So, for example, in quantum electrodynamics, it is proved that the gauge field, the source of which is the conserved charge of the electron, is an electro-magnetic field, which is described by Maxwell's equations. And the gauge particle (quantum of the gauge field), which carries electromagnetic interactions, is a massless photon with a spin equal to unity. The same takes place in quantum chromodynamics, the theory of strong interactions. Here, the field particles are 3 colored varieties of quarks, the gauge field is the field of strong interaction, and the gauge particle of this field is glion, a massless particle with spin equal to 1. In the theory of weak interactions, the gauge field is a weak field, the gauge particles are the components intermediate vector boson [1–3] with spin also equal to unity. Finally, in the theory of gravitation (general relativity) the gauge field is the gravitational field, the gauge particles are massless hypothetical gravitons with spin equal to 2, and the source of the field is the conserved mass.

On the other hand, sources of local symmetric fields, by definition, must be point, massless formations. In other words, the mass of elementary particles under these conditions would have to be equal to zero, and, according to the theory of relativity, they would have to move with the maximum possible speed of light. Interactions and the formation of bound atomic (real) structures would then be impossible.

To eliminate this contradiction, English physicist Peter Higgs put forward a hypothesis in the middle of the last century, according to which, even at the beginning of the Universe, the gauge symmetry of fundamental fields was violated by another massive exotic field, which was called the Higgs field. Under the influence of the Higgs scalar field, particles exchange energy quanta with it. As a result, they are structured and acquire corresponding, strictly defined masses, which lead to a decrease in their speeds and a change in the direction of movement. At the same time, some of them emit quanta of the corresponding field, while others, having the same gauge, absorb them. As a result of the exchange interaction, quarks bind into protons, neutrons and mesons, forming atomic nuclei, and electrons bind to nuclei, forming atoms, molecules and various real atomic-molecular conglomerates [1, 2, 4].

In other words, the Higgs field has a decelerating effect on the particles interacting with it, while the resistance of the Higgs field increases with increasing particle acceleration. For clarity, the mechanism of action of the Higgs field can be compared with the movement of light particles in a liquid. If we first assume that the fluid is ideal, that is, it does not have viscosity, then at the slightest perturbation the particles begin to move intensively, accelerating, as if they do not have any mass. On the contrary, the same particles in a highly viscous liquid remain almost motionless, that is, they acquire very small accelerations even with sufficiently strong perturbations. This means that they behave as if under the influence of a viscous liquid they have acquired sufficiently large masses.

The interaction of the Higgs field with various particles is selective. It interacts most strongly with intermediate vector bosons, imparting to them a colossal mass of the order of 80 GeV and 90 GeV, which is almost 100 times the mass of a proton. Its interaction with quarks is much smaller, its interaction with leptons is even weaker, and its interaction with neutrinos and, possibly, with dark matter particles is negligible. The Higgs field does not interact at all with photons, gluons, and possibly hypothetical gravitons.

Calculations show that to ensure the known masses of elementary particles, the mass of Higgs particles should be in the vicinity of 125–126 GeV. This is a huge mass, exceeding 130 times the mass of a proton. To detect high-energy Higgs particles, conventional particle accelerators have proven unsuitable. In this regard, the Large Hadron Collider (LHC) was built at the European Center for Atomic Research (CERN). In the collision of beams of protons accelerated in the accelerator to a very high, near-light speed, energy is released that is equivalent to the mass indicated above. If Higgs particles exist, then under the action of the specified energy they should appear among many other born particles and can be captured using special detectors (Fig. 2, 3).

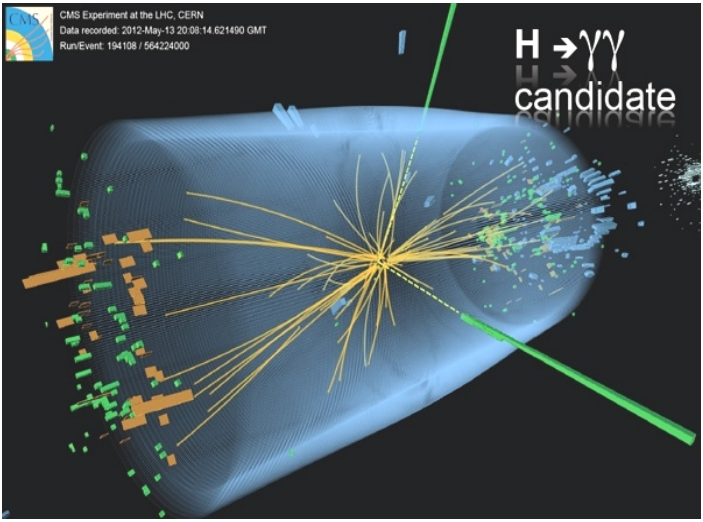

Fig. 2. One of the Higgs boson birth events and its decay into 2 photons

Of course, Higgs particles are short-lived and cannot be directly observed. They can, however, be detected by the observed decay products, in this case, photons (There are other mechanisms for the decay of Higgs particles). Already a year after the launch of the collider, particles with a mass attributed to the Higgs particles were discovered.

Fig. 3. One of the two LHC detectors. CERN

Thus, particles and the Higgs field, predicted purely theoretically, were discovered after half a century as a result of persistent, purposeful search. This very rare event is significant in itself. However, its main significance lies in the fact that it once again very convincingly and with high reliability confirmed the standard model underlying the model of the universe that is currently accepted.

Does this mean, as they say and write about it, that with the confirmation of the existence of the Higgs field, the standard model has received its final completion and has become, as it were, absolute truth in the last resort? From our point of view, this is far from the case. The fact is that the Higgs theory, like, by the way, any new theory, gave birth to more questions than it answered.

On the one hand, it filled in a very important gap in the standard model and answered the eternal question of physicists about the sources of interactions and driving forces in the Universe, which Plato and Aristotle posed back in their time. It also made it possible to better understand the nature of the mass of elementary particles and confirmed the unified field theory, which made it possible to combine the electromagnetic and weak interactions. It turned out that it is the Higgs field that imparts mass to the gauge intermediate vector bosons, which, together with massless photons, carry electroweak interactions. Finally, based on the fact that the Higgs field is the source of the masses of leptons and quarks, imparting mass to all material formations, physicists were able to explain how the entire real Universe was formed from structureless non-material virtuality.

On the other hand, the understanding of the Higgs field and particles has led to many new questions. First, if the Higgs bosons are the source of the mass of elementary particles and, consequently, of all material formations of the Universe, then the question arises, what is the source of the mass of the Higgs particles themselves? Secondly, the standard model has many other problems. These include the problems of divergences, problems associated with the theory of grand unification and with unsuccessful attempts to extend the unified field theory to gravity, dark matter and energy that do not fit into this model, etc.

Many of these problems are the result of attempts to uncritically extend the standard model to conditions where it has an approximate character. The point here is that the relativistic quantum field theory, taking into account the provisions of the special theory of relativity, ignores the general theory of relativity, considering quantum processes not in a curved Riemannian, but in a flat pseudo-Euclidean space-time.

In addition, the mathematical apparatus of quantum field theory, i.e. The theory of Feynman diagrams and the theory of gauge symmetry ignore the structure of elementary particles, considering them as point formations, which, as a result of taking into account self-action, leads to divergences. True, with the help of the renormalization procedure and taking into account the spontaneous symmetry breaking that arose under the action of the Higgs field, they were eliminated for electromagnetic, strong and weak interactions. The idea of renormalization is that the mass of a particle is not calculated, but is assumed to be equal to the value measured experimentally.

Theoretically, this is justified by the fact that the actual mass of the particle is the sum of the positive field (equivalent to the energy of the motion of the particle) and the negative seed (bare), i.e. the rest mass of the particle under the assumption that it has no charge (equivalent to the binding energy of the particle). Because the charge is inseparable from the particle (movement is inseparable from the connection), then each of these masses separately has no physical meaning. The seed mass is selected in such a way that the sum of the indicated masses is equal to the actual mass.

Then the positive infinite field mass at the particle localization point is compensated by the negative infinite seed mass, which is equal to zero outside the particle localization point. So, for example, in quantum electrodynamics (QED):

$$m_e = \frac{e^2}{32\pi^2 \cdot \varepsilon_0 \cdot c^2} \cdot \frac{dV}{r^4} - m_0 \cdot c^2. \qquad (4)$$

However, gravitational interactions cannot be renormalized. At the same time, the general theory of relativity does not take into account the quantum nature of microprocesses and the need for space-time quantization.

These approximations, admissible to some extent in the region of low energies, become inadmissible in the region of high energies, for example, in black holes, the initial Universe.

At present, as is known, attempts are being made to eliminate these shortcomings and to combine quantum field theory and general relativity into a unified theory of quantum gravity. It has been called the theory of everything. But not in the sense that this theory, when it appears, will be able to solve all the problems of the standard model. Moreover, there is no doubt that any theory of everything will, in turn, create many new problems. Such is the law of the progressive development of any science, because, according to modern ideas, absolute truth does not exist in principle, especially since recently facts have appeared that even cast doubt on the existence of objective truth. However, there is now an intensive process of searching for the theory of quantum gravity. There are already many approaches to it. The most realistic options that claim to be able to form the basis of the theory of everything in the near future are superstring theory, including the theory of supersymmetry, as well as loop quantum theory. At present, none of them can answer all the questions, each of them also has dubious and even contradictory points. But if we try to unite these theories, excluding contradictions from them and using everything that corresponds to the future theory in them, then we can already show a certain optimism today. The introduction of the Higgs field into the standard model is not only not a hindrance, but, on the contrary, as we have seen, it helps to solve this problem.

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