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THE GREAT UNIFICATION

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ABSTRACT

The philosophical foundations and conceptual difficulties of the theory of the grand unification in physics are considered. It is shown that, despite the urgency of this problem, it cannot be solved without a conceptual study of the foundations of physical theories.

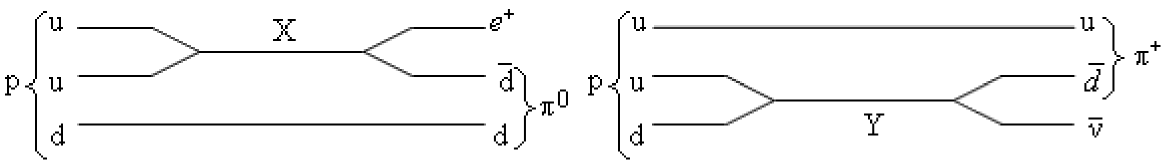
Keywords: methodology, foundations of scientific theory, theory of the grand unification.

INTRODUCTION

The Grand Unification is the unification at ultra-high energies of the three fundamental interactions - strong, electromagnetic and weak. A prerequisite for the unification of the three mentioned interactions is that the forces (intensities) of these interactions, which are fundamentally different at ordinary (low) energies, with an increase in energy and, accordingly, a decrease in the distance between particles, approach and, according to estimates, converge at an energy 1015-1016 GeV (≈10-29 cm), called the point of the Great Unification.

As the energy grows (starting from the lowest), the strong, electromagnetic and weak interactions merge into a single one in two stages. At an energy of 102 GeV (distance 10-16 cm), the electromagnetic interaction merges with the weak into an electroweak one. The formation of electroweak interaction is an established fact and its theory has been created (electroweak model). At the point of Grand Unification, the electroweak interaction merges with the strong one. This merger is a hypothesis. The hypothetical bosons X and Y, which have huge masses of 1015 - 1016 GeV / s2, are considered to be the carriers of the forces of the Grand Unification.

Despite the fact that it is impossible to artificially create the conditions for the Grand Unification due to the fantastic energies required for this, there are a number of qualitatively new effects predicted by this unification, which can be tested in laboratory conditions. This is how the Grand Unification (TVO) theories predict the decay of a proton into a positron and a neutral pion.



In this decay, neither the baryon nor the lepton quantum number is conserved (these numbers were conserved in all the observed processes), and the time of such decay in the simplest TVO is about 1030 years. Such decays have not been found, and the lower time limit for such decay is 1032 years.

The conditions for the Great Unification could exist in the Universe for a short period immediately after the Big Bang, i.e. about 13-14 billion years ago, when its age was 10-43-10-36 s.

Great unification in physics means the creation of a theory that will uniformly describe all four types of interactions known today: gravitational, electromagnetic, strong and weak. Currently, a unified theory of three interactions has been built: electromagnetic, weak and strong, but the fourth - the gravitational interaction described by the general theory of relativity - stands alone. Gravity is different from other fields, "because gravity forms an arena on which it itself acts, as opposed to other fields that act in a given space-time" [1. P. 12]. The first three theories are quantum, they assume the presence of a minimum portion of the received and emitted energy - A quantum, the theory of relativity is basically a geometric theory and connects the force of gravitational interaction with the characteristics of space itself. The problem of unification in a more special language is formulated as the impossibility of quantizing gravity. This is due to the understanding of the action of gravity as a curvature of space-time, on the one hand, and the quantum-mechanical principle of uncertainty, on the other. The uncertainty principle speaks of the impossibility of simultaneously obtaining arbitrarily accurate knowledge of two conjugate quantities, for example, coordinate and momentum. The uncertainty principle unites several physical quantities - the concept of simultaneity, spatial coordinates and dynamic characteristics, the action of causality and conservation laws. According to this principle, the area of deterministic causality does not apply to the phenomena of the microcosm, but refers only to macroscopic phenomena. General theory of relativity (GTR) is a macroscopic theory, but in order to combine it with the existing theories of the microworld, it must be translated into "quantum language", i.e. give a formalized description of this theory at the micro level.

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When quantizing gravity, problems arise in understanding causality. At the macro level, general relativity is a deterministic theory. This means that locally, in each region of space, one can find a solution to the Einstein equations and determine the metric. Since the agent carrying the gravitational interaction is space itself, it is space that must be quantized. But when we go to the region of infinitesimal scales, we are faced with the operation of the uncertainty principle, which indicates the impossibility of determining the metric due to quantum fluctuations of the field.

In our opinion, the problem of combining theories is rooted in an inconsistent understanding of the ontological foundations of various physical theories. A number of ontological principles speak in favor of this point of view, as well as the content of the conceptual foundations of physical theories. The latter are understood as the fundamental categories used in physics, but going beyond the purely physical understanding due to their universality: space, time, causality, matter. Ontological foundations are also understood as a number of methodological principles of physics with ontological premises, which will be considered below.

The methodological principle is understood as a cognitive system, explicable through accumulated knowledge and functioning in scientific knowledge. Methodological principles arise as a result of a person's striving for knowledge of the world and impose functional restrictions on knowledge (epistemology) and vision (ontology) of the world. The world, thus, is structured due to the practical activities of man, and his vision is theorized [2. S. 217]. The method is a more general education [3. P. 44].

The relevance of the problem of unification is due to both the philosophical and ontological premises and the conceptual difficulties of theoretical physics itself, as well as the applications of physics in the field of cosmology.

The philosophical and ontological premises are based on the principle of the material unity of the world, which postulates the integrity and unity of nature. In the course of scientific research, scientists concentrate on individual features of the phenomena being studied, which in the future need to be put into a holistic picture. "Once upon a time all natural phenomena were roughly divided into classes ... [reductionism] The goal, however, is to understand all of nature as different sides of one set of phenomena. This is the task of fundamental theoretical physics of the present day: to discover the laws behind experience, to unite these classes [synthesis]. Historically, sooner or later it was always possible to merge them, but time passed, new discoveries arose, and again the task of including them in the general scheme arose "[4. T. 1. S. 39]. The principle of material unity functions in the form of a desire to synthesize fundamental categories (entities) of physics (for example, space and time, particle and field) and finds expression in the unification of a number of physical concepts. So, the concept of matter at the modern level of development of the theory unites not only material and field concepts, but also space-time.

The philosophical foundations include the principles associated with the principle of unity and arising from it. For example, the postulate of the universal connection of phenomena, or the principle of simplicity, according to which our knowledge of the world must have an essential unity. The unity of the world is also indicated by the principle of symmetry, concretized in the form of various conservation laws. "The general conservation law, concretized in the form of various particular physical conservation laws, underlies a single physical picture of the world" [5. P. 15]). The functioning of the methodological principle of unity is manifested in the form of the existence of physical pictures of the world. "The main tendency of every physical picture of the world is to give a single harmonious reflection of objective reality" [6. S. 213]. In addition, its action is manifested either in the form of a formal-logical combination of physical theories, or in the form of their synthesis. For example, string theory is the amalgamation of two field theories: general relativity and quantum field theory. In addition, unification is a direction of the mathematical development of the theory associated with the search for solutions to the Einstein equation and overcoming a number of theoretical problems, one of which is the problem of the existence of singularities.

The conceptual difficulties of physics include, for example, the problem of vacuum energy. The crux of the problem is that theoretical predictions of the vacuum energy are 120 orders of magnitude higher than the observed value. The extension of the Standard Model entails a new type of symmetry, in which the difference between baryon and lepton charges is conserved and the existence of new types of superpartner particles is predicted. Taking into account the contribution to the vacuum energy of superpartner particles makes it possible to reduce the discrepancy by more than 40 orders of magnitude.

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The problem of unification is of particular practical relevance thanks to cosmology, since if in physics itself this problem is rather of theoretical interest, then in cosmological studies the existence of objects has been established, for the description of which the combined application of both the theory of relativity and quantum mechanics is required. These are objects similar to black holes formed during gravitational collapse, when matter is compressed to high-density states, entering a singular state with infinite curvature.

In addition, it has been established that all the matter of the present Universe was concentrated in an extremely small spatial region about 1010 years ago. This follows from the fact of the expansion of the Universe and from the equations of the theory of relativity, therefore, an attempt to set the initial conditions will lead to a singularity, near which the radius of curvature of space can be arbitrarily small. The questions following from the assumption of the initial singularity concern causality, the explanation of local inhomogeneities of the type of star clusters under the assumption of homogeneity and isotropy of space.

Despite the acuteness and high urgency of the problem, it has not yet been resolved. The two most authoritative approaches to this problem - loop quantum gravity theory and string theory - Have difficulty asking questions.

These are experimental evidence and therefore are not generally accepted. Accordingly, the purpose of the article is to point out ontological difficulties on the way of building a unified theory. These difficulties are of an ontological nature, since natural science theories take on an ontology that serves to describe the world. Historically, the ontology of various theories was formed in different epochs based on different prerequisites, therefore, a number of basic physical concepts have incompatible descriptions.

For example, the category of space was originally understood in the first physical theory - Newtonian mechanics - as a 3-dimensional empty container of objects and processes. This understanding was inherited by quantum mechanics, which considers space to be independent of matter. In the theory of relativity, space and time are equal and united into a 4-dimensional smooth manifold, the curvature of which depends on the distribution of masses and energies. That is, space and matter are closely related at the conceptual level, the distribution of matter determines the properties of space. A contradiction arises when trying to combine two approaches, in one of which space and matter are closely interrelated, while in the other they are considered in isolation. In the transition to quantum scales, according to the principle of uncertainty, there is an uncertainty in the values of energy-momentum, which, according to the theory of relativity, is accompanied by the curvature of space. Thus, at the micro level, the structure of space-time is subject to fluctuations, which is inconsistent with the smoothness of the geometry of space at macroscales. "The standard resolution of Zeno's paradoxes is based more on the mathematical concept of the continuum than on the nature of spacetime itself. The assertion that space-time forms a continuum implies the preservation of its continuous nature, regardless of what "increase" we consider it with. But it is by no means obvious that the continuous description corresponds to reality on a sufficiently small scale, where quantum effects play an essential role. Take, for example, scales of the order of 10-13 cm (the approximate radius of an elementary particle). Any attempt to determine the position of a particle with this degree of accuracy becomes likely (due to the uncertainty principle) that an extremely large momentum will occur. Then new particles should be born, and some of them may turn out to be indistinguishable from the original, so that the concept of the "position" of the original particle becomes indefinite. But an even more threatening picture emerges when we dare to move on to phenomena occurring on scales of the order of 10-33 cm.Here, quantum fluctuations in the curvature of space-time become strong enough to change the topology, and space-time should turn out to be some kind of disordered superposition of various topologies, and this certainly does not look like a smooth manifold "[7. S. 11-12]. The use of new methods leads to the fact that space is no longer considered as a separate entity and becomes part of a more general concept.

In the understanding of matter in quantum mechanics, a discrete approach dominates: the parameters of particles and fields are considered as quanta. The characteristics of massive particles are considered independently of the space-time parameters; the ideas of symmetry dominate in the description of the particle parameters. Within the framework of quantum field theory, particles transform into each other due to symmetry breaking. The mass of elementary particles is determined by the absorption of a quantum of a scalar field - the Higgs boson. In relativistic theories, heavy mass is reduced to inert mass by establishing the equivalence of the gravity field to an accelerated frame of reference. Mass determines the geometry of space-time, the kinematics of bodies is determined by the curvature of space. In the theory of quantum gravity, which inherits the conceptual apparatus of relativistic theories, the concept of matter remains insufficiently developed. In string theory, on the contrary, the concept of matter is worked out in great detail and a different apparatus for generating masses is proposed, associated with the vibration energy of a fundamental object - a string. However, string theory has a number of problems, the main one being the lack of experimental evidence. In particular, the supersymmetric particles predicted by string theory have not been detected in experiments at the Large Hadron Collider.

Differences in the conceptual apparatus also affect such a fundamental category as causality. The theory of relativity, like classical mechanics, are deterministic theories. The action of causality in the theory of relativity is limited by the surface of the light cone, which serves as the boundary of the region of propagation of signals emanating from a given point. Due to the limited speed of light, not any events are causally connected, but only those from which information can be transmitted at a speed less than or equal to the speed of light. In relativistic theories, causality is not considered in isolation, but is determined through space-time characteristics (light cone) and constant - the speed of light.

In quantum mechanics, causality is more of a statistical nature, although it is generally accepted that a quantum system, left to itself, evolves deterministically. But the measurement process introduces perturbations due to which the evolution of the system is disrupted and the measurement results turn out to be probabilistic. The Heisenberg Uncertainty Principle speaks of the fundamental impossibility of obtaining arbitrarily accurate information about all the characteristics of the system simultaneously. The influence of the observer on the system leads to an uncontrolled change in the parameters of the system. In general, the analysis shows the incompatibility of the philosophical foundations of scientific theories and allows us to consider the problem of unification from the standpoint of the inconsistency of theoretical views on the main ontological categories. The opposing views today were formed historically, the theories within which this or that conceptual description was formed, developed on different grounds. In our opinion, the construction of a unified theory without unifying the philosophical foundations of theories is impossible. The solution to the problem of compatibility of conceptual foundations could be solved by a certain common language in which interpretations of concepts could be given in such a way, to be consistent with the language of any physical theory. However, such a language is not yet available.

CONCLUSION

The idea of creating a universal language was expressed at the end of the 19th century, and within the framework of logic and mathematics, much was done to create a universal mathematical language. An essential feature of this language is its formality, i.e. refusal to consider substantive, including metaphysical, grounds. The mathematical language began to be used in many sciences, including physics, where the formal mathematical approach itself was inherited. The rejection of metaphysics, explanation and meaningful interpretations was especially characteristic of the creators of quantum mechanics, who were influenced by the value attitudes of positivism. Metaphysics was denied; the task of science was to banish metaphysics. Later, in the 1960s, it was realized that metaphysics in theory is always present in the form of the most general assumptions about the laws of nature and the structure of the world. But since scientists for the most part proclaimed a refusal to consider metaphysics in science, the basic scientific concepts, which are on the border of science and philosophy, turned out to be unworked. Metaphysics played the role of a carpet under which uncomfortable problems swept like rubbish. However, a problem that has been abandoned does not cease to be a problem. At present, the positivist attitude towards exclusive attention to formalism is becoming an obstacle to the development of science in the field of unification of theories. The very concepts of space, time, matter and causality need deep conceptual processing, which requires efforts from both scientists and philosophers.

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