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ON THE MOTION OF MATTER IN THE GEOMETRICAL GAUGE FIELD THEORY

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Коноплева Н. П. E2-2005-160
О движении материи в геометрической теории
калибровочных полей

В геометрической теории калибровочных полей уравнения движения материи (элементарных частиц) связаны с уравнениями поля. В данном докладе обсуждаются проблемы, возникающие из-за этой связи. Впервые подобные проблемы возникли в общей теории относительности Эйнштейна. Эйнштейн надеялся, что решение этих проблем позволит объяснить природу элементарных частиц без использования квантовой механики. Но оказалось, что ситуация более сложная. Здесь формулируются соответствующие проблемы для связи уравнений движения частиц и уравнений поля в геометрической теории калибровочных полей. Показано, что появление обсуждаемых проблем является неизбежным следствием перехода к релятивизму и локальным симметриям.

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Konopleva N. P. E2-2005-160
On the Motion of Matter in the Geometrical Gauge Field Theory

In the geometrical gauge field theory, the motion equations of matter (elementary particles) are connected with the field equations. In the talk, the problems arising from this connection are discussed. For the first time, such problems arose in Einstein's General Relativity. Einstein hoped that solution of these problems will allow explanation of elementary particles nature without making use of quantum mechanics. But, as it turned out, the situation is more difficult. Here the corresponding problems are formulated for the connection of equations of particle motion and field equations in the geometrical gauge field theory. It is shown that appearance of the problems under discussion is an inevitable effect of passage to relativism and local symmetries.

The investigation has been performed at the Bogoliubov Laboratory of Theoretical Physics, JINR.

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Talk dedicated to the 125th jubilee of A. Einstein and to the centenary of D. Ivanenko, who was the first to riddle nucleus structure

Two fundamental concepts are assumed by modern physics: matter and fields. The matter can exist both in discrete form (point particles, extensive bodies) and in the form of continuously distributed medium in space (liquids, gases, solid bodies). In the classic theory a field is always regarded as continuous something filling the whole space. But properties of this field are not mechanical.

Before GR creation it was supposed that all events being under physics consideration happen against a vacuum background. The vacuum is the world state corresponding to absence of both fields and particles. It is absolute, universal, and global, that is its properties are the same at every point of space and at each instant of time. The vacuum properties are not connected with matter motion and field properties. Just this vacuum is postulated in Newtonian mechanics, relativistic mechanics, and field theory without GR.

Such a vacuum is a passive arena of events. But in reality we assume that *the vacuum state corresponds only to particle absence (or other matter).* In experiments a backing pump is often the tool for making a real vacuum state. Therefore, our assumption immediately leads us to relativism.

Even in Newtonian mechanics appearance of gravity is followed by loss of equal states of all space-time points. Particles behavior becomes depending on space-time point, and in this sense localization of particle motion laws arises. It can be said that in space without particles (or other matter) gravity induces localization of vacuum properties. Such a vacuum is no longer a global one. Similarly the local transformation of the vacuum for charged particles will arise if electromagnetic field appears.

GR appearance changed our perception of gravitational field, space and time properties, and also of substance behavior in Universe. Moreover it necessitated to revise the vacuum properties. It was found that relativistic vacuum properties must be described by vacuum Einstein equations.

Usually in Maxwell's electrodynamics the law of charged particles motion is regarded as logically independent of the field equations. Therefore, it must be added to them.

In GR the field equations with arbitrarily moving sources are absent. The motion of particles is determined by the same equation system that determines propagation of fields.

How is it possible to solve the equations which simultaneously determine field and motion of particles? Einstein with his collaborators went into this problem in 1927 (with Grommer) [1] and in 1938 (with Infeld and Hoffmann) [2].

They showed that the motion law of test particles (i.e. the motion along geodesic lines of Riemannian V_4) can be found as a corollary of the field equations. Therefore, it is not necessary to postulate the motion equations in addition to the field equations.

So, *for the first time it was shown that field theory could include a theory of mechanical motion of matter.* Einstein hoped to find an explanation of elementary particles nature (specifically electron) and quantum theory laws in this way.

But in the above Einstein's papers geodesic line equations were only obtained for the field singularities (gravitational field or gravity with electromagnetic field). Thus, *electron was described as moving field singularity.* In the proof, approximate solutions were used.

These results and ones of the ensuing years were summarized in the L. Infeld and J. Plebansky monography «Motion and Relativity» of 1960 [3].

Thus, the first solution of motion problem in GR was found by Einstein in 1938.

But in 1939 V. A. Fock proposed a quite different way to solve the problem [4, 5]. He showed that for massive extensive noninteracting bodies the motion equations can be obtained from Einstein equations as their corollary. They are also the geodesic lines equations. Moreover, he put a question: What kind of real objects and under which conditions can be the objects of application of GR? V. A. Fock found that such objects were cosmic bodies as planets and stars being long distant from each other, but in no way it could be elementary particles. He took for granted that GR can not be applied to microworld objects. Fock's point of view is explained in his monography «Theory of space, time and gravitation» of 1955 [6].

By another method the same result was found by N. P. Konopleva in 1977. In paper «Gravitational experiments in cosmos» [7] I discussed the conditions ensuring realization to given precision of GR axioms in cosmic experiments. Distinctive feature of these experiments consists in existence of many factors exercising their influence on test bodies. It was found that under these conditions it was very difficult to make an object which would behave as pure gravitational test body of GR. It is a complex technical problem for artificial objects. For natural objects I obtained a formula which arrived at a conclusion that the real massive bodies could appear as the test bodies, when their radii were large enough. Estimation shows that within $10^{-8}g$ (g is acceleration due to gravity) planets and stars can be regarded as GR test bodies, but elementary particles cannot be regarded in this way. Even nuclei can only give precision of geodesic motion $\sim 10^{-5}g$. It is insufficient for extraction of GR geodesic trajectories from all perturbed Newtonian ones. Therefore, elementary particles are poor test bodies. They cannot precisely move along geodesic lines in real conditions.

But recently a new possibility of GR application to microworld was discovered. In the framework of geometrical theory of gauge fields it was shown by me that relativistic vacuum in classic theory of gauge fields was Einsteinian vacuum which was described by vacuum Einstein equations [8, 9]. Hence, it is necessary to return to the question about connection between elementary particles and GR. This is the question of a connection between fields and matter both in microworld and in macroworld.

Now Wheeler's results of 1955 become again very interesting [10]. J. A. Wheeler and C. W. Misner demonstrated in 1957 the third independent solution of motion problem in GR [11]. At first it seems to be paradoxical. They have shown that having only free electromagnetic and gravitational fields in vacuum without any singularities or massive bodies there can be constructed such solutions of Einstein–Maxwell equations which are everywhere regular and localized. These solutions describe objects which far from their centers look like massive neutral or charged particles in spite of the fact that neither mass nor charge is inside them. This effect results from nonlinearity of theory and nontrivial topology of Riemannian V_4. Wheeler's point of view is explained in his book «Neutrinos, gravity and geometry» of 1960 [12].

It is necessary to note that in pure gravitational field without any matter or other fields regular solutions of vacuum Einstein equations do not exist. For example, presence of singularity, statics, and Schwarzschildean form of the solution arise from only its spherical symmetry. This fact is known as Birkhoff theorem [13]. Schwarzschild solution of 1916 [14] was strong, analytical and had singularity at point $r = 0$ (r radius). Single constant which defines this solution was interpreted as a mass of gravity source. Geodesic lines were considered trajectories of test bodies (or massless particles) moving in the field of this point source. But what kind of equations is guiding the motion of gravity source? It remained unknown. Schwarzschild solution corresponds to null right side of Einstein equations, i.e. vacuum.

So, Einstein equations permit us to obtain as their corollary the motion equations of neutral particles and massive bodies, and also Lorentz equations describing charged particle motion in external electromagnetic and gravitational fields.

This indicates that in a sense Einstein equations contain mechanics and classical electrodynamics of moving particles and, hence, *permit us to overcome dualism of matter and fields.* Final answer will be given after clarification of connection between Einstein equations and quantum physics laws.

The attempts to find this connection were launched by many scientists both in USSR and in other countries. In USSR Prof. D. Ivanenko was leading in this direction during many years [15]. His papers, books, and scientific organizational activities promoted intensive development of science working in gravity and GR. The above-cited books of Infeld and Plebanski and also Wheeler were published in Russian thanks to Prof. D. Ivanenko. At that time I was a third-year student of Moscow University and took part in translation of these books from English into Russian. They seemed to be very difficult to me but attracted like a magnet, and until now I think about problems from these books. They stimulated my interest in geometrical theory of interactions.

Creation of geometrical gauge field theory by the end of 1960s [16] put again the same questions that were in GR. But now they concern a wider class of elementary particle interactions. Einstein equations are components of equation system of geometrical gauge field theory [17]. All equations of this theory have clear geometrical meaning in terms of fibre bundle space geometry. Thus, not only gravity and electromagnetism but also nuclear forces have a geometrical treatment.

Just as it is in GR, in geometrical gauge field theory the motion equations can be obtained as a corollary of the field equations. But it is necessary to note that theory of nonlinearity is not a cause of this effect.

When we go over from global space-time symmetries to the local ones, which are defined by coordinate transformations $x^{\mu'} = f^{\mu}(x^{\nu})$, and f^{μ} is arbitrary continuous function, four identities arise according to the second Noether theorem [16]. Just these identities reduce number of independent equations. Therefore, four equations of motion turn into a corollary of the field equations. Covariant conservation law of energy-momentum tensor of the system of particles and fields corresponds to the above local coordinate transformations and Noether's identities. Just it permits us to connect the equations of fields and particles with each other. Therefore, *the connection between fields and particles is a direct result of localization of symmetries and relativism.*

NOW EINSTEINIAN PROGRAM IS OPENED AGAIN! We must make a try at understanding of elementary particles nature through field equations.

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