Covariant theory of gravitation

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The history of appearance and characteristics of covariant theory of gravitation (CTG) and its difference from the general theory of relativity (GTR) are described. CTG is developed as an axiomatic theory based on five axioms using the language of 4-vectors and tensors, and is derived from the principle of least action and through Hamilton equations. In CTG gravitational radiation of any body is based on equation of its motion and has a dipole component. In GTR we proceed from the tensor nature of metric field and take into account all the bodies of considered material system at once, and therefore the basis of gravitational radiation is only the quadrupole component. The CTG Hamiltonian is obtained in two ways – either through 4-velocity or through generalized 4-momentum.

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Introduction

Covariant theory of gravitation (CTG) was introduced in 2009 [1] as an alternative to the general theory of relativity (GTR). CTG generalizes equations of Lorentz-invariant theory of gravitation (LITG) to non-inertial reference frames. LITG is valid only in case of inertial frames of reference [2], [3], and is based on extended special theory of relativity [4] and Le Sage's theory of gravitation [5]. For transition from LITG to CTG it is necessary not only to write equations of motion for field and substance in a covariant form, but also to use metric theory of relativity (MTR) [1]. In CTG gravitation is a real physical force, and gravitational field has its own stress-energy tensor. In contrast, in GTR gravitation is reduced to geometric curvature of spacetime and to metric field, the energy of which can not be determined unambiguously.

LITG

According to axiomatics of LITG [1], each moving mass creates around itself not only the gravitational field strength $\boldsymbol{G}$, but also gravitational torsion field $\boldsymbol{\Omega}$. The gravitational field equations in LITG are similar by form to Maxwell equations for electromagnetic field (see Maxwell-like gravitational equations and selfconsistent gravitational constants), and in this case $\boldsymbol{G}$ corresponds to electric field strength $\boldsymbol{E}$ and $\boldsymbol{\Omega}$ is similar to magnetic field induction $\boldsymbol{B}$. With the help of $\boldsymbol{G}$ and $\boldsymbol{\Omega}$ energy density of gravitational field, vector of field energy flux

(Heaviside vector), gravitational tensor (field strengths tensor) and gravitational stress-energy tensor are determined. The connection between the two components $\boldsymbol{G}$ and $\boldsymbol{\Omega}$ of gravitational field leads to effect of gravitational induction.

In LITG not only strengths but also potentials of gravitational field – scalar potential ψ and vector potential $\boldsymbol{D}$ are used. The scalar and vector potentials form gravitational four-potential. Each of the variables $\boldsymbol{G}$, $\boldsymbol{\Omega}$, ψ and $\boldsymbol{D}$ can be determined from corresponding wave equation, the solution of which is integral over the spatial volume, taking into account the delay time of gravitational effect propagation from the moving mass to the point of observation.

Within LITG is put forth [6] and the problem 4/3 is solved [7], which is associated with mass-energy of gravitational field.

CTG features

The equations of CTG differ from the equations of LITG since they are valid not only for Minkowski space, but also for Riemannian space. In CTG the same idea as in GTR and other metric theories is used: it is assumed that in any accelerated and therefore non-inertial reference frame the spacetime is curved. The degree of spacetime curvature at each point in space is characterized by curvature tensor which is a function of metric tensor and depends on the stress-energy tensors of substance and field at this point. Mathematically this is expressed in Hilbert-Einstein equations for the metric. In contrast to GTR, in CTG in the right side of this equation the stress-energy tensor of gravitational field is included. Thus the gravitational field becomes an independent source of spacetime curvature, as the substance and electromagnetic field. CTG can be developed on the axiomatic basis [1], [8].

The structure of CTG includes three types of equations – to determine metric, to calculate strengths and potentials of gravitational and electromagnetic fields, and to find motion of substance under action of fields and mechanical stresses. In the curved spacetime the components of metric tensor become functions of spatial coordinates and time, which allows us to describe additional changes of dimensions and time intervals that occur in accelerated reference frames in comparison with inertial frames. For writing the equations of CTG definitions of four-force, of operator of proper-time-derivative, of invariant energy and principle of energies summation are used.

All equations of CTG can be derived from the principle of least action [9]. In this case the meaning of cosmological constant is found – it is proportional to mass m' of substance of the considered system, taken without including mass-energy of gravitational and electromagnetic fields. In contrast to GTR, Hamiltonian in CTG contains terms related to energy of gravitational field [10].

By introducing into theory of generalized 4-velocity s_μ we can achieve more simple writing of Lagrangian and Hamiltonian, besides the product ms^μ sets the generalized 4-momentum. Another newly introduced thing is the 4-vector H_μ, in which the Hamiltonian is time-like component. Being written with the covariant index, the 4-vector H^μ is 4-vector of energy-momentum, setting relativistic energy and momentum of substance taking into account contributions from existing gravitational and electromagnetic fields.

The consequences of CTG

CTG predicts the existence of three types of body mass: mass m' is the sum of masses of the body's parts, scattered at infinity, which allows us to exclude the contribution of mass-energy of macroscopic gravitational and electromagnetic fields from the body's substance into the mass; mass M determines the inertial and gravitational properties of the body and is the relativistic mass; body's mass m and the substance density corresponding to this mass are included in Lagrangian and Hamiltonian. In GTR two masses are usually used, M and m, and mass m is treated as the rest mass of the substance without taking into account the energy of fields.

According to CTG, in the absence of electromagnetic field the ratio between the masses is as follows: $m' < M < m$, $m - M \approx M - m'$. This allows us to understand the controversy arising in interpretation of the mass. In particular, in GTR we proceed from the mass m, adding to it the mass-energy of gravitational field we obtain the mass M. Since the mass-energy of the gravitational field is negative, the ratio for the masses is: $M < m$. In CTG we proceed from the mass m', from which we should subtract the mass-energy of gravitational field in order to obtain the mass M. This leads to inequality $m' < M$. The need to subtract the field energies in CTG is proved in [7], [9], [11] for different situations. Interestingly, in CTG the masses m' and M can be measured experimentally, while the mass m must be calculated.

According to [1], for the case of an isolated body at rest in the components of metric tensor there is an additional term, which is inversely proportional to the fourth power of gravitation propagation speed. The characteristic feature of solution for static case is dependence of metric tensor on two constants that can be found from comparison with experiment. Rotation of a body leads to emerging in the metric tensor of an additional constant which depends on the angular momentum of the body (a similar effect in GTR is seen in Kerr metric). Due to the presence of indefinite constant coefficients in the solution for metric, CTG can describe any gravitational phenomena and interactions of bodies, including shift of perihelion of planets, gravitational redshift, time dilation in gravitational field, deviation of motion of test particles and field quanta near massive bodies, precession of orbits and gyroscopes etc.

Another consequence of the theory is associated with the difference of equations of motion in GTR and CTG: in GTR free motion of a test body in gravitational field is described as 4-acceleration of the body equal to zero. In CTG equation of motion has the classical form: in the left side of the equation there is the total derivative of momentum with respect to proper time, and in the right side there is the sum of gravitational and electromagnetic forces. In [1] attention is drawn to the fact that difference of equation of motion in CTG from equation in GTR is sufficient to explain the "Pioneer" effect.

Metric theory of relativity

According to [1] and [8], MTR is based on five axioms and is considered as a theory, which includes the special theory of relativity and the part of GTR which refers to the methods of conversion of physical quantities from one reference frame to another. In MTR it is assumed that spacetime measurements can be carried out not only by electromagnetic waves but also by other waves, as well as by test particles. These waves and particles can have different speeds of propagation and motion, which affects the results of space and time measurements of the same events in different reference frames. An example of this is Lorentz transformations, which depend on the speed of electromagnetic waves (speed of light) as a parameter. In GTR the metric tensor components are also dependent on the speed of light. In MTR the generalization of principle of equivalence is used as the principle of local equivalence of energy-momentum. All this means that the spacetime metric in each frame depends entirely on the method of measurement, including the speed of signal propagation and other properties of the signal carrier. For example, measurement of metric around a massive body by spinless test particles and particles with spin will give different results.

Strong gravitation

According to infinite hierarchical nesting of matter and SPΦ symmetry, at each basic level of matter its own gravitation is acting. It is assumed that at the atomic level strong gravitation is acting, the strong gravitational constant differs from the ordinary gravitational constant and equations of strong gravitation are equations of CTG. Strong gravitation explains the cause of rest energy, the structure and integrity of elementary particles, and strong interaction between the particles [1], [12].

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