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THE MEANING OF MODERN RELATIVITY

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...the principle of relativity imposes conditions which all physical laws have to satisfy. It profoundly influences the whole of physical science, from cosmology, which deals with the very large, to the study of the atom, which deals with the very small

P.A.M.Dirac[1]

INTRODUCTION

The special theory of relativity in its form generally accepted at present was in fact formulated at the beginning of our century. From the origin its construction was based on the radar procedure used, for example, for the synchronization of distant clocks and what is more this procedure served for Einstein as a direct derivation of the Lorentz transformation [2]. As known, historically the transformation was obtained from the invariant condition of Maxwell's equations when passing to a moving (inertial) reference system.

Relativity theory made revolutionary changes in the representations of space and time going back to Newton. It opened new ways of trying to understand natural phenomena and served as the basis for relativization of many fields of physics including electrodynamics, mechanics, thermodynamics and so on. However, the process of origin and formation of new presentations cannot be completely separated from the previous notions at once. Because of their habitualness these old notions «being unnoticed» are going on to serve the theory which rejects them in essence. First of all, this concerns the concept of rigid rod. Ideed, such fundamental essence as a reference system is thought to in the form of a frame of rigid rods and a set of synchronized clock placed at different points [3]. We would remind that the representation of a rigid (undeformed) rod was adopted from daily life in which we deal with very small (with respect to light) velocities. In essence, undeformation means that perturbation propagated, for example, from one end of the rod to the other one practically instantly. Otherwise one can say that the rigid rod realizes an instant (simultaneous) length. In the non-relativistic case this condition is actually fulfilled, and such a representation is quite justified. However, for motion velocities close to the light one, the velocity of deformation propagation is a small value. Nevertheless, we continue to hold our previous positions subconsciously, i.e. to use the representation of rigid bodies. One known elementary derivation of the relation $E=mc^2$ [4] can be a typical example here, where it is implicitly that a rigid cylinder begins to move instantly [5] due to the radiation of a light flash. Hitherto this derivation is often adduced when relativity theory is started (see, e.g., [6]).

Another completely covariant formulation [7,8] operates with light or retarded distances directly observed in experiment and leans on the radar method of distance measurement [9]*. Thereby in the frame of this formulation we get rid of series of fictitious notions and, in the first place, such as rigid scales (rods). This approach is related to the «asynchronous formulation» [12] purely mathematically.

One can conclude already on the basis of the foregoing that the main difference of the two approaches must be connected with the behaviour of space sizes of materil bodies. Indeed, if in the first case we have the contraction of longitudinal sizes of moving objects, in the second one their elongation takes place.

The main aim of this paper is to state basic peculiarities of the covariant formulation and its difference from the traditional (Einstein's) approach.

1. THE TRADITIONAL (EINSTEIN'S) APPROACH

Just this approach is expounded in all text-books and monographs on relativity theory. The aspect of our interest concerns mainly a space part of the space-time picture (i.e. such notions as length, distance and quantities formed on their basis).

We would remind that according to Einstein, the length of a moving rod is called the distance between simultaneous positions of its ends [2]. Below for brevity the generally accepted approach leaning upon this definition following Born [6] is named Einstein's theory of relativity (ETR). It is obvious that its definition includes any small velocities of rod motion, i.e. in the limit and the rod at rest. Thus, one can say that in the frame of the traditional approach we deal with simultaneous or instant distances (cf. with the instant form of Dirac's relativistic dynamics [1]).

At the same time one of the main merits of relativity theory is to ascertain the relativity of simultaneity, i.e. its noninvariance or dependence on reference

*It should be stressed that the previous approach [10,11], whose basis are observers supplied with similar clocks and radars, has rather a formal character. Therefore as a result of the transition to instant distance all conclusions corresponding to Einstein's approach remain in force.

system. It is evident that the same defect will be inherent in the physical notion leaning on the simultaneity condition ($t=\text{const.}$). Just for this reason the generally accepted definition of length (connected with the determination of simultaneous positions of rod ends) contradicts the principle of relativity as it depends on a reference system*.

In the mathematical language these discorses come to a very simple demand. The introduced physical notion must be covariant, i.e. a moving rod must be described by a space-like 4-vector. The generally accepted definition of moving rod length gives a recipe of obtaining corresponding four numbers in each reference system. If the Lorentz invariance condition is fulfilled, these four values must represent the same 4-vector. Or otherwise, the interval corresponding to the contracted length must be a Lorentz-invariant one.

The relativistic interval is a four-dimensional quantity defined by two point events and is an analog of three-dimensional distance between two points. Or as one says, the metric of Minkowski's (four-dimensional) space is defined by the interval squared

$$-s^2 = c^2\Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2, \tag{1}$$

depending on the coordinate difference of these events. The interval is the main invariant of relativity theory, and so it is also named the fundamental invariant. Clocks and scales (rods) are material representatives of the interval.

Remined that the interval is a quantity which does not change (it remains an invariable one) when transitting from one inertial reference system to another one. Since this transition is related to changing motion velocity, the interval invariance must mean its independence (constancy) of velocity**.

Let us consider the traditional (Einstein's) definition of moving rod length l_E from the viewpoint of the foregoing. Let for simplicity the rod be oriented and move along the x-axis of S-system. In the framework of this definition it is characterized by two simultaneous events at its ends or a four-component quantity

$$l_E^n = (0, \Delta x, 0, 0) = (0, l_E, 0, 0). \tag{2}$$

Therefore the space-like interval answering this moving rod takes the form

$$s_E = \Delta x = l_E. \tag{3}$$

As known, a direct consequence of the simultaneity demand of endmark $\Delta t = 0$ (simultaneity of this pair of events) is the contraction formula

$$l_E = l^*(1 - v^2/c^2)^{1/2}. \tag{4}$$

*In this connection see also [13].

**In view of importance of the statement, below we prove a special theorem on this account.

Here l^* is the rod length at rest (proper length) and v is its velocity (the velocity of the S^*-system relative to S).

Based on (4), it follows that the interval s_E depends evidently on the motion velocity

$$s_E = l^*(1 - v^2/c^2)^{1/2}. \tag{5}$$

As noted above, such a dependence means that *the traditional definition does not satisfy the Lorentz invariance condition of interval* [14]. Or otherwise, the contracted length is not a 4-vector component [15], and consequently the generally accepted definition does not satisfy the demand of Lorentz covariance.

But from the viewpoint of relativity theory it is a terrible sentence meaning in essence that there is no place for simultaneous (instant) length in this theory.

Certainly, it arouses astonishment that this important check (of the interval invariance of the rod) was not carried out after introducing Minkowski's 4-geometry [16] although the very statement of a question is formulated in the known «Lectures on physical foundations of relativity theory (1933—1934)» by L.Mandel'shtam [17], where it is said that «immoving scale measures a space-like interval», i.e. $s = l^*$.

It would be quite appropriate to remind here about the principle of observability as well. According to it, one should not introduce non-observable quantities into science*. In other words, it is impossible to propose such operations which are not realizable for measuring these quantities. The known Einstein's (macroscopic) mark procedure of simultaneous position of the ends of a moving rod with the help of a great number of clocks placed in space and preliminary sychronized does not give rise to objections at first sight. But in practice the main field of relativity theory application is the phenomenon of microworld which this procedure is simpy inapplicable to.

2. MODERN APPROACH (CAMPLETELY COVARIANT FORMULATION)

The essence of the covariant formulation consists in that it deals with distances directly observed in experiment (in particular, measured by the radar method) between nonsimultaneous points. As known, in electrodynamics these distances

*As one states [18], the traditional definition «is a completely useless concept in physics». «Nobody will ever see the Lorentz contraction. To define it operationally, one has to assume an infinite velocity of light, contrary to relativity, i.e., in contradiction with the theory that supposedly introduces that definition». Also [19]: «It is obvious therefore, that Lorentz contraction, as defined in the special relativity, is not an observable effect, or, which is the same, is not a real physical phenomenon».

are called retarded. Still earlier similar (light) distances were applied to determine the aberration angle of star light.

One can say that the transition to the covariant formulation is connected with the removal of actually non-observed (i.e. fictious) instant distances. As a result, the space-time structure, the basis of relativity theory, suffers a radical change. In particular, we have an increase of longitudinal sizes of relativistic objects (the elongation formula) instead of familiar contraction.

2.1. The Concept of Covariant (Radar) Length

Light or retarded distances. The notion of «light distance» arose in essence long before the origin of relativity theory. Just the light distance defines the aberration angle. The aberration of star light is the phenomenon known long ago which was first observed as early as 1727 by Bradley [20].

However, the immediate usage of such distances is connected with the Lienard-Wiechert potential [21,22]. For the electric potential created by point charge e moving with velocity $\mathbf{v}$, we have

$$\Phi = \frac{e}{R_{ret}(1 - \boldsymbol{\beta}\mathbf{n})} = \frac{e}{R_{ret}(1 - \beta\cos\vartheta)}. \tag{6}$$

Here $\mathbf{R}_{ret}$ is the vector of the retarded distance between the charge and the observation point, $\boldsymbol{\beta} = \mathbf{v}/c$, $\mathbf{n} = \mathbf{R}_{ret}/R_{ret}$. Using the transformation formula for the potential and taking into account that in the rest system of the charge the field is described by Coulomb's potential

$$\Phi^* = \frac{e}{R^*} \tag{7}$$

we obtain [23]

$$R^* = R_{ret}(1 - \beta\cos\vartheta)\gamma, \tag{8}$$

where $\gamma = (1 - \beta^2)^{-1/2}$. This equation expresses the transformation law for retarded distance when passing from the proper system S^* of the source to the S-system where it moves with velocity $\mathbf{v}$. Certainly, the formula (8) can be also derived directly from the Lorentz transformation for time. For two of the most characteristic cases when the field propagates in the direction of source motion (forward, $\vartheta = 0$) and in the opposite direction (backward, $\vartheta = \pi$) we have

$$R_f = (1 + \beta)R^*\gamma, \tag{9}$$

$$R_b = (1 - \beta)R^*\gamma. \tag{10}$$

The covariant (radar) length. The nontraditional definition of relativistic length [24,25] is based on the radar method of measuring distances*. In its frames, for example, the propagation time of a light signal in the forward and backward directions along the rod is measured. This is identical to the corresponding procedure used to verify the formula for relativistic time retardation. In fact, on the basis of the latter we arrive at the elongation formula. Here we give another derivation of it.

For simplicity, suppose that the rod is oriented and moves in the direction of the x-axis (from left to right) with velocity $v = \beta c$. A signal is sent at the instant of passing the left end. The light reaching the right end is reflected there and returns to the left end. For the distance covered by the light signal, when it moves forward, in the same direction as the rod (overtaking the right end of the rod) we have

$$l_f = l^*(1+\beta)\gamma. \tag{11}$$

Here l^* is the length of the rod at rest. This formula is the direct consequence of substituting quantities $\Delta x^* = l^*$ and $\Delta t^* = l^*/c$ answering the light signal propagation along the resting rod (in the direction of x-axis) in the Lorentz transformation

$$\Delta x = (\Delta x^* + \beta c \Delta t^*)\,\gamma, \tag{12}$$

when changing the direction of light propagation, we must change the sign of the space coordinates in (12). Thus, when the light signal (after reflection) moves in the direction opposite to that of rod motion (toward the left end of the rod), it traverses the distance

$$l_b = l^*(1-\beta)\gamma. \tag{13}$$

As a result, for the covariant (radar) length we find

$$l_r = \frac{1}{2}(l_f + l_b) = l^*\gamma \text{ (elongation formula)} \tag{14}$$

We emphasize that l_f and l_b define distances between points taken at different times, i.e., they obviously correspond exactly to the two most characteristic modifications of retarded distances (9) and (10) in electrodynamics.

In the framework of the four-dimensional representation, the covariant length is given by the spatial part of the half-difference of the two 4-vectors that describe the processes of light propagation in the forward and backward directions along the rod. In the moving S-system the 4-vector of covariant length is of the form

*One can say that introducing this method, a moving observer simply «spies» the procedure of measuring the length of the rest rod (in another reference system) but uses his own measuring devices (clocks).

$$l_r^i = (\beta l^*\gamma,\ l^*\gamma,\ 0,\ 0). \tag{15}$$

For this we have for the interval squared

$$s_r^2 = (l^*\gamma)^2 - (\beta l^*\gamma)^2 = (l^*)^2, \tag{16}$$

i.e., the Lorentz invariance demand is satisfied.

We draw the readers attention to the recently published book [26] where both existing approaches are considered in detail, and preference is given to «the hypothesis of length expansion». Also, «the logical contradiction in the process of deriving the length contraction» is accounted. Besides, note the statement [19] of the importance of «the retarded length» as the basis of «relativity theory (in contrast to the special relativity theory)».

2.2. The Previous Difficulties of Theory Are Removed

«Problem 4/3». Its main point is that we come to the formulae which differ from the required relativistic ones when calculating the electromagnetic field energy and momentum of a moving charge

$$G^n = [(1+\beta^2/3)\,\mu c\,\gamma,\ (4/3)\,\beta\mu c\,\gamma,\ 0,\ 0]. \tag{17}$$

Here $\mu = E^*/c^2$, E^* is the electromagnetic energy of a charge at rest. We note at once that this result is a direct consequence of using the contraction formula for a space volume element. At the same time the use of elongation formula (14) does not lead to a similar difficulty (see, e.g., [27]).

It should be emphasizes that in the frames of this problem the very first indirect evidence of contracted length noncovariance (exactly, contracted volume) was obtained when Laue used the obviously covariant expression

$$G^i = \int T^{ik} dV_k\,. \tag{18}$$

Here T^{ik} is the energy-momentum tensor of the electromagnetic field, dV_k is the four-dimensional quantity that has only one time component in accordance with the generally accepted definition (see, e.g., [29])

$$dV_n^E = (dV^E,\ 0,\ 0,\ 0) = (dV^*\gamma^{-1},\ 0,\ 0,\ 0). \tag{19}$$

Since the Lorentz covariance of T^{ik} is beyond doubt, it is obvious that the «source of noncovariance» is the element of the contracted volume.

It should be stressed that the formula of space volume increase corresponding to (14) was first introduced [30] just when solving the «problem 4/3». But may be it is particularly important that within the frames of the covariant formulation there is no need to ascribe to charge an extra mechanical mass which is due to «Poincare stresses».

The «paradox» with the capacitor energy or the violation of the law of energy conservation. The electrostatic energy of a plane-parallel capacitor, which plates are normal to the x^*-axis, is equal to

$$E^* = \varepsilon^* V^* = \frac{(\mathcal{E}_x^*)^2}{8\pi} \sigma l^*, \tag{20}$$

where ε^* is the energy density of an electric field $\mathcal{E}_x^*$, σ is the area of the plates, l^* is the gap between them. As $\mathcal{E}_x^*$ (and, consequently, ε^*) and σ are not transformed when passing to the moving S-system, the formula for energy of a moving capacitor

$$E = \varepsilon V = \varepsilon^* \sigma l \tag{21}$$

is practically defined by l. If in accordance with ETR, we take contracted length l_E, then evidently we come to a contradiction with the known relativistic formula $E = E^*\gamma$. What is more, in this case the energy of a moving capacitor is smaller than its energy at rest. Though, as known, in order to set a capacitor in motion, it is necessary to spend some energy (it is transferred to the capacitor).

Thus, in the framework of ETR we also have the contradiction with the law of energy conservation conditioned again by the use of noncovariant contracted length.

A similar difficulty does not arise if l is given by the radar length l_r [27] which, in accordance with (14), increases proportionally to γ as it is required.

On the charge of a current-carrying conductor or the violation of the law of charge conservation. Let us consider an element of a line conductor at rest (directed along the x^*-axis) which the current with density j_*^1 flows along. Let the densities of negative and rest positive charges ρ_-^* and ρ_+^* be equal, and therefore the total density be $\rho^* = 0$. Thus, from the viewpoint of an observer from the S^*-system the wire does not take a charge

$$\Delta q^* = \rho^* \Delta V^* = 0, \tag{22}$$

where Δq^* is the charge and ΔV^*, the volume element of the conductor.

Let us transit now to such a reference system relative to which negative charges are at rest. Based on the transformation formula for the total density in S, we obtain

$$\rho = \rho_- + \rho_+ = -\rho_-^* \beta^2 \gamma. \tag{23}$$

Attracting the volume contraction formula $\Delta V = \Delta V^* \gamma^{-1}$ corresponding to (4), we conclude that from the viewpoint of the S-system the wire has a positive charge (see, e.g., [6a, 32]

$$\Delta q = -\rho_-^* \beta^2 \Delta V^*. \tag{24}$$

Thus, it is evident that in the frames of ERT the invariance of an electric charge violates. What is more, this result may be interpreted otherwise. A neutral current-carrying conductor takes a charge (without removing electrons outside) as a result of motion. In other words, the use of noncovariant quantity has led us to the violation of the law of charge conservation.

In the frames of the covariant formulation

$$\Delta q = j^i \Delta V_i, \tag{25}$$

where the 4-vector of a volume element

$$\Delta V_i = (\Delta V^* \gamma, -\beta \Delta V^* \gamma, 0,0). \tag{26}$$

As a result, we obtain

$$\Delta q = j^0 \Delta V^0 + j^1 \Delta V_1 = (-\rho_-^* \beta^2 \gamma) \Delta V^* \gamma + (-\beta \rho_-^* \gamma)(-\beta \Delta V^* \gamma) = 0, \tag{27}$$

i.e., the demand of charge Lorentz invariance is really fulfilled, and, consequently, the charge is conserved.

For the last few years the considered example is discussed (see e.g., [33] and references therein) in connection with the following question: does the electric charge appear in an electrically neutral conductor after current excitation in it? This means that the current arises only due to setting conductivity electron in motion. Since in this case the number of electrons does not change and as before it is equal to the number of positive ions, one can speak of the appearance of a electric field due to the difference in the behaviour of the fields moving and resting charges (see, e.g., [34]).

The Lewis-Tolman «paradox» of a right-angled lever [35]. The essence of this known problem lies in the appearance of a torque ($N_z \neq 0$) in the reference system S, where a lever is moving while in its proper system S^*

$$N_z^* = X^* F_y^* - Y^* F_x^* = 0. \tag{28}$$

Here X^* and Y^* are the lever arms directed along the x^*- and y^*-axes F_y^* and F_x^* the forces applied to them with $X^* = Y^* = l^*$ and $F_x^* = F_y^* = F^*$. On the basis of the principle of relativity and in the S-system an analogous equality should be valid which we present in the form

$$XY^{-1} = F_x F_y^{-1}. \quad (29)$$

According to the transformation formulae for force components $F_x/F_y = \gamma$, whence for the transformation of the longitudinal arm we have the elongation formula (14). At the same time the application of the contraction formula leads to the violation of equality (29) and appearance of one of the most known «paradox» of relativity theory. The right solution of this paradox was first given by Arzelies only in 1965 [36].

Other difficulties (*and their removal*) are one or another analogs to the cases considered above. Therefore we restrict ourselves only to their enumeration.

Let us begin with one more example of relativistic formulation of statics — the treatment of the classical Trouton-Noble experiment with a changed capacitor [37] (it is similar to the last example). The other classical Michelson-Morley experiment can be also explained without using the contraction hypothesis [5].

Within the framework of the covariant formulation the problems rigid body dynamics are solved successively [38]; in particular, we point to little known «paradox» of Einstein [39]. By analogy with the «problem 4/3» the difficulty with the momentum and energy of liquid is removed [40].

2.3. Direct Experimental Verifications of the Covariant Formulation

The relativistic Doppler effect. As far as we know, at present the wave length of an orange line of crypton-86 is in fact assumed to be the standard of length. On the basis of (14) we obviously have the transformation formula of wave length

$$\lambda = \lambda^* \gamma. \quad (30)$$

According to the demand of the principle of relativity, the number of wave lengths packing up in the moving standard meter remains actuall unchangeable. As it follows from (30), the wave length of light radiated by moving atoms must increase as follows

$$\delta\lambda = \lambda - \lambda^* \simeq \frac{1}{2}\beta^2\lambda^*. \quad (31)$$

Just this phenomenon is observed in experiments on the investigation of the relativistic Doppler effect; the first of them was realized by Ives and Stilwell [41].

We note that the change of wave length (when moving) to the red end of the spectrum (red shift) is the well-known fact as well as formula (30) (see, e.g., [42]). However, in this case it is lost sight of that we have in essence another law (different from the generally accepted one) of transformation of the length of a moving scale. Indeed in formula (30) λ describes, for example, the distance between the neighbouring combs of a wave which «are taken» at different instants

whereas according to the generally accepted (Einstein's) definition, the distance between simultaneous positions of its ends is called the length of a moving scale. When the contraction formula is valid, the effect should have another sign, i.e. the shift of the lines should occur to the violent end of the spectrum.

Cherenkov's radiation. The Lienard-Wiechert electrical potential in medium with refractive index n is*

$$\Phi = \frac{e}{n^2 R(1 - \beta\cos\vartheta)}. \quad (32)$$

As it follows from the last expression, the potential becomes infinite at

$$\cos\vartheta_C = (\beta n)^{-1} \quad (33)$$

that corresponds to the appearance of Cherenkov's radiation. Virtual quanta of the electromagnetic field are converted to real photons of visible light at the expense of a sharp increase of the field energy density. It should be stressed that for this the Cherenkov angle is given just by the retarded (light) distance. On the other hand, the usual transition (in accordance with Einstein's approach) to instant distances (see, e.g., [43a])

$$R(1 - \beta n\cos\vartheta) \to R_s(1 - \beta^2 n^2 \sin^2\Theta)^{1/2} \quad (34)$$

leads us to Heaviside's potential [44]

$$\Phi_H = \frac{e}{n^2 R_s(1 - \beta^2 n^2 \sin^2\Theta)^{1/2}}. \quad (35)$$

As known, the generally accepted representation of the field of a moving charge in the form of spheroid is the consequence of this very expression. But this transition (34) leads to the change of the radiation angle. Indeed, as one can see, Heaviside's potential turns into infinity at the angle

$$\Theta = \text{arccosec}\,\beta n \quad (\Theta > \pi/2). \quad (36)$$

But since in experiment (for example, in Cherenkov counters) ϑ_C is measured, this means that just the covariant formulation is adequate to nature. On the other hand, the transition to the observation moment can be considered as, in its way, the violation of the relativity principle. Indeed, in so doing the observation moment is distinguishable with respect to the radiation one. In other words, as if the equality between the radiating charge and the registering device is violated.

In the conclusion of this part we present comparative Table 1 of some distinctive results of the former (Einstein's) approach and the modern formulation.

*Below we omit index «ret» and, on the contrary, introduce index «s» for the instant or synchronous distances.

Table 1

EINSTEIN'S APPROACH	MODERN FORMULATION
Transformation of longitudinal sizes	
$l = l^*\gamma^{-1}$	$l = l^*\gamma$
Energy of a physical object	
$E = mc^2$	$E = m\gamma c^2$
Torque of a system in equilibrium	
$N_z^* = 0$ $(F_x^*, F_y^* \neq 0)$, $N_z \neq 0$	$N_z = N_z^* = 0$
Momentum and energy of electromagnetic field	
$G_x = \frac{4\beta}{3c}E^*\gamma$, $E = (1+\beta^2/3)E^*\gamma$	$G_x = \frac{\beta}{c}E^*\gamma$, $E = E^*\gamma$
Electrical potential	
$\Phi_H = \frac{e}{R_s(1-\beta^2\sin^2\Theta)^{1/2}}$	$\Phi_{LW} = \frac{e}{R(1-\beta\cos\vartheta)}$
Charge of a current-carrying conductor	
$q \neq q^*$ (charge non-invariance)	$q = q^*$
Transformation of electric dipole moment	
$d_\parallel = d_\parallel^*\gamma^{-1}$, $d_\perp = d_\perp^*$	$d_\parallel = d_\parallel^*$, $d_\perp = d_\perp^*\gamma$
Transformation of heat, temperature and pressure	
$Q = Q^*\gamma^{-1}$, $T = T^*\gamma^{-1}$	$Q = Q^*\gamma$, $T = T^*\gamma$
$p = p^*$	$p_\parallel = (p^* + \beta^2\varepsilon^*)\gamma^2$, $p_\perp = p^*$
Relativistic Doppler effect	
$\lambda = \lambda^*\gamma$ (elongation formula)	
Cherenkov angle	
$\mathrm{cosec}\,\Theta = \beta n$	$\sec\vartheta = \beta n$
Time inversion	
$E \to E$, $\mathbf{p} \to -\mathbf{p}$, $\mathbf{M} \to -\mathbf{M}$	$E \to -E$, $\mathbf{p} \to \mathbf{p}$, $\mathbf{M} \to \mathbf{M}$
$\Phi \to \Phi$, $\mathbf{A} \to -\mathbf{A}$	$\Phi \to -\Phi$, $\mathbf{A} \to \mathbf{A}$

2.4. New Results of Theory

2.4.1. Kinematics and Mechanics

The Lorentz invariance of interval means its independence of velocity, i.e. constancy [14]. In view of importance of this statement, we formulate it as a theorem and prove it [45].

The theorem. *If an interval does not depend on motion velocity, it is Lorentz-invariant.*

For clearness we suppose that $s = l^* f(\beta c)$, where l^* is the constant, $f = (1-\beta^2)^a$, and βc — the velocity. We imply a moving rod as a material representation of the interval.

Necessity. Let $a = 0$. Then in two reference systems, where the rod moves with the velocities βc and $\beta_1 c$, we have

$$s = l^*(1-\beta^2)^0 = l^* \quad \text{and} \quad s_1 = l^*(1-\beta_1^2)^0 = l^*,$$

i.e., the demand of interval invariance $s = s_1$ is really fulfilled.

Sufficientness. It is obvious that the demand of the Lorentz invariance is observed if the equality

$$l^*(1-\beta^2)^a = l^*(1-\beta_1^2)^a$$

is valid. But this is possible if $a = 0$ only (since $\beta \neq \beta_1$).

So, the theorem is proved. The inverse theorem can be proved as easily as the theorem.

As in relativity theory a 4-interval takes the place of the previous «pre-relativistic» invariant — distance (length), one should say more correctly about the interval of a rod instead of its length. In the rest system of the rod, i.e., in essence in the non-relativistic limit, their values coincide that ensures the succession of corresponding theories and necessary uniqueness of the interval. Taking into account of the interval Lorentz invariance leads only to the «radar definition» of the moving rod length.

On the other hand, the space-like interval is defined by the length of a resting rod. In a moving system its «space part» (the rod length in motion) because of the negative sign (pseudo-Euclideanness) is always greater than the interval itself. And this means again that bodies elongate (but not contract) when moving.

Visible sizes of a moving rod. Just when considering this problem [46,47], doubt on the unconditionedness of the previous theory statement of the contraction of moving bodies was first cast. As it was founded, the «mean visible size» is just defined by the radar length. On the other hand, this problem exceeds the limits of simple visual observations and turns out in essence to be decisive when the interaction of moving charged particles in an ondulator, the passage of charged clot through a resonator and so on are considered [48].

The addition rule of 4-velocities u^i and v^i is defined by formulae [49]

$$U^0 c = u^i v_i, \quad U^\alpha = u^\alpha + v^\alpha \frac{u^0 + U^0}{v^0 + c}, \qquad (37a,b)$$

here $U^i = dX^i/d\tau$ is the relative velocity, i.e., the 4-velocity of one particle in the rest system of another one, $\alpha = 1,2,3$.

Using the relative 4-velocity, in particular its space-like component, i.e., $|\mathbf{U}|$, one can considerably simplify some well-known relations. Among them is the expression for the number of collisions $d\nu$ occurring in the volume element dV over the time dt (see, e.g., [43b])

$$d\nu = \sigma v_{\mathrm{rel.}} n_1 n_2 dV dt. \tag{38}$$

Here σ is the interaction cross-section, n_1 and n_2 are the densities of particle beams. Its relativistic generalization looks as

$$d\nu = \sigma |\mathbf{U}| n_1^* n_2^* dV dt, \tag{39}$$

where n_1^* and n_2^* are the beam densities in their rest systems. This formula is more obvious than the conventional expression [43b] with the utilization of the Moeller flux.

Non-covariance of the law of energy inertia (LEI) or the law of mass and energy equivalence [50]. As known, LEI is considered as one of the main results of the special theory of relativity. It is mathematically expressed by Einstein's famous formula

$$E = mc^2. \tag{40}$$

For the first time the statement that an inert mass should be ascribed to any energy E was voiced by Einstein [31] as long ago as the «pre-covariant» period of relativity theory, i.e., before its four-dimensional formulation (in the late tenth). However, in his article of 1912 we read: «One of the main results of the theory of relativity is the statement that any energy E has the proportional to it inertia (E/c^2)» [4]. Further on, Einstein returns repeatedly to the proof of formula (40).

Although LEI is considered as a consequence of relativity theory it contradicts its very essence. Mass and energy equivalence takes place only in the rest system when a material body after energy loss (say, in the form of radiation) remains at rest. In all other reference systems such equivalence does not take place since the mass is a Lorentzian scalar (invariant) and energy is the component of a 4-vector. What is more, if energy answers any mass, then mass answers not any energy. A detailed discussion of this problem can be found in Okun's article [51].

Thus, Einstein's formula (40) is valid only in the rest system. In general, the Lorentz-covariant relation between mass and energy is given by Minkowski's formula [16]

$$E = m\gamma c^2 \tag{41}$$

that is the time component of the known equation (see, e.g., [43c])

$$p^i = mu^i, \tag{41'}$$

where p^i is the 4-vector of energy-momentum.

2.4.2. Electrodynamics

The form of the electric field of a moving charge. Based on the Lienard — Wiechert potential, equipotential curves for relativistic charge are given by the equation of an ellipse [52]

$$R = a(1 - \beta \cos \vartheta)^{-1}. \tag{42}$$

Here $a = e/\Phi$ is the focal parameter and β the eccentricity of the ellipse that evidently streched in the motion direction. As it follows from (42), the field of the charge is drawn out forward as its velocity increases and acts at ever greater distances. For longitudinal and transverse sizes we have

$$R_{\parallel} \sim 2\gamma^2 a, \quad R_{\perp} \sim 2\gamma a. \tag{43}$$

One can say that there is a kind of relativistic long-range effect [53]. But the main thing is that this field behaviour differs significantly from its habitual representation as a spheroid described by the equation

$$R_s = a(1 - \beta^2 \sin^2 \Theta)^{-1/2}, \tag{44}$$

which follows from formula (35) at $n = 1$.

Macroscopic sizes of field of super-relativistic changes [54]. The behaviour of longitudinal and transversal sizes of the electromagnetic field of proton and electron with increasing their velocity is presented in Table 2. The atomic size $a = 1$ Å that answers the production of the simplest bound system, for example, of the indicated particles, is taken as an initial one. As is seen, at a proton energy of $E_p = 10$ TeV the longitudinal size of the field is 2 cm(the transverse one is 2 μm); for an electron with an energy of $E_e = 50$ GeV, $R_{\parallel} = 2$m, $R_{\perp} = 2$ μm. To the point, the known relativistic growth of ionization losses is just conditioned by the considered effect. For cosmic particles of relatively low energy of $E_p = 10^3$ TeV the longitudinal size reaches a very large value of 200 m ($R_{\perp} = 0.2$ mm). Thus, one can say that elementary particles acquire characteristics of macroscopic objects. Therefore the division into micro- and macroobjects becomes in a sense conditional (relative). What is more, at high energies the production of atoms of macroscopic sizes becomes possible.

Attention should be given to the fact that at an energy of 10^{16} eV the field of a cosmic particle (proton) only entering the atmosphere already reaches the surface of the Earth. At $E = 10^{18}$ eV the longitudinal size is $2 \cdot 10^5$ km, i.e., it is much larger than the Earth diameter. A longitudinal field size of $2 \cdot 10^9$ km is significantly larger than the distance from the Earth to the Sun for cosmic particles of maximum energy of 10^{20} eV.

Table 2

E_p, TeV	0	0.07	1	10	10^3	50	5	E_e, GeV
$R_{\parallel}$, mm	10^{-7}	10^{-3}	0.2	20	$2\cdot10^5$	$2\cdot10^3$	20	$R_{\parallel}$, mm
$R_{\perp}$, μm	10^{-4}	0.015	0.2	2	200	20	2	$R_{\perp}$, μm

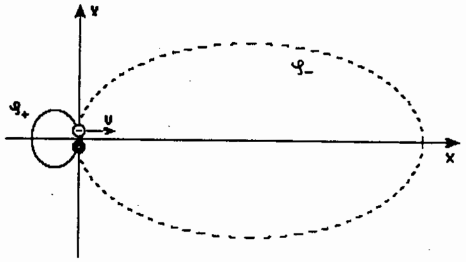

Fig.

The electric field oscillation of atoms [55] is a direct consequence of the different field behaviour of moving and resting changes. Let us consider the simplest Bohr atom formed by a resting positive charge (nucleus) and a moving negative one (electron). The equipotential curve answering the given position of electron is presented in the figure*. As seen, the atom looks like a neutral one only at an angle of $\varphi=\pi/2$ to the motion direction of electron. In the «forward» direction the atom seems negatively charged and «backward» — positive. Or otherwise, as the electron rotation leads to the change of directions of its motion, then at the given observation point the atom potential will oscillate according to the formula

$$\Phi \simeq \frac{e}{R}\cdot\frac{\beta\sin\varphi}{1-\beta\sin\varphi}. \tag{45}$$

Here φ is the polar angle of electron in the plane of its rotation, where the effect is maximum. Although the amplitudes of different signs differ, the mean (per period) value of the potential is equal to zero owing to the influence of the Doppler effect.

As elementary particles are also composite systems according to the modern representations, an analogous effect takes place for them.

Relation of the formation length with the field sizes of a moving charge [54].Remind that the concept of formation length (way) was introduced by I.Frank [56] when considering the radiation of a uniformly moving oscillator in a refractive medium. He defined it as the interval of the path which waves are radiated by a source in phase. The corresponding formula (for refractive index $n=1$) is of the form

$$l_f=\frac{\lambda\beta}{1-\beta\cos\vartheta}, \tag{46}$$

where λ is the wave length of radiation; ϑ the angle between the directions of wave emission and charge motion.

*In order to stress the effect, we take $\beta=0.75$ although for Bohr atom $\beta\approx10^{-2}$.

As it follows from a simple comparison of equations (46) and (42) all the peculiarities of the formation length behaviour simply reflect the field behaviour of a moving charge. For this the radiation itself can be interpreted as «knocking out» quanta of the charge «accompaniment field».

Based on the Lienard — Wiechert vector potential, by analogy with (42) we have

$$R_A=\frac{e\beta}{A(1-\cos\vartheta)}. \tag{47}$$

Now we would like to pay attention to the following. The radiation of a moving charge is in essence the conservation of virtual quanta to real ones. Based on the electromagnetic coupling constant, it follows that the ratio of the interaction energy of two charges e^2/λ at distance λ which is carried by a virtual photon to the energy of a born real quantum with wave length λ is $\alpha/2\pi$. Indeed,

$$\frac{\alpha}{2\pi}=\frac{e^2}{\lambda}\Big/\frac{hc}{\lambda}. \tag{48}$$

Substituting the corresponding relation for momentum ($eA=\alpha hc/\lambda$) in (47), we obtain

$$R_f=\frac{e^2\beta}{(\alpha hc/\lambda)(1-\beta\cos\vartheta)}=\frac{\beta\lambda}{1-\beta\cos\vartheta}. \tag{49}$$

Thus, expressions (49) and (46) derived in absolutely different ways are completely coincident. It should be stressed that the behaviour of both the field sizes and the formation length are essentially defined by the «retardation factor» $\kappa=1-\cos\vartheta$. This factor defines on the whole the intensity of «velocity radiation» (as bremsstrahlung, though). Therefore the larger the formation length, the more the probability of quantum emission just in this direction.

The radiation conditioned by the «velocity part» of the electromagnetic field of a moving charge. Its varieties are the following: Cherenkov's radiation, transition radiation and radiation in gas below Cherenkov threshold. At large velocities for the radiation intensity in a solid angle element we have [57]

$$W_v \simeq \frac{e^2\beta c}{4\pi n^4 R^2}\,\frac{\sin\vartheta(1-n+n^2)^{1/2}}{\gamma_n^4(1-\beta n\cos\vartheta)^6}, \tag{50}$$

where $\gamma_n=(1-\beta^2n^2)^{-1/2}$. As seen, all radiation is concentrated in a very narrow cone around the direction of a particle motion. In the limit $\beta\to1$ this radiation can serve as a direct target designation of a particle. Certainly, this fact is the direct consequence that the relativistic charge field is stretched forward and not squeezed in the motion direction. This property of the field forward direction of a relativistic charge explains, in particular, the empirical rule for finding the direction of the optical transition radiation emitted «backward» when a particle is flying into medium. According to it, the radiation is «going» in the particle velocity direction and is reflected from the surface like from the mirror.

It should be noted that the discussed radiation is considerably weaker than the radiation of the field «acceleration part».

The «Cherenkov bremsstrahlung» [58,59]. On the other hand, the bremsstrahlung intensity to a solid angle element, when the velocity and acceleration are parallel, is described by the formula

$$W_b = \frac{e^2}{4\pi nc^3}\,\frac{w^2 \sin^2\vartheta}{(1-\beta n\cos\vartheta)^6}. \qquad (51)$$

When the condition (33) is fulfilled, this term also increases sharply. One can say that we have its way of Cherenkov bremsstrahlung (CB). As far as one can judge, this phenomenon has been observed in the experiment [58] recently. In the very general case we have another («mixed») term side by side with (50) and (51).

At the same time the energy loss for Cherenkov's radiation by a uniformly moving charge is evidently accompanied by its braking that leads to the appearance of the field «acceleration part» and consequently to the «induced» CB.

The power-force tensor [5] is an analog of the energy-momentum tensor and it also serves to describe the continuous distribution of matter. For example, the electromagnetic power-force tensor takes the form.

$$P^{ik} = \frac{1}{c}\, j^i F_l^{\,k} u^l, \qquad (52)$$

where F^{ik} is the electromagnetic field tensor.

2.4.3. Thermodynamics

Ott's formulation of thermodynamics [60] was proposed in the beginning of the 60s and is different from the traditional one tracing back to Plank [61] and Einstein [3]. In the framework of the traditional approach, for example, the transformation formula for temperature is

$$T = T^*\gamma^{-1} \qquad (53)$$

whereas Ott offered

$$T = T^*\gamma \qquad (54)$$

following from the corresponding transformation formula for heat amount ΔQ.

The equation of the state of ideal gas connects temperature and space volume. For this the demand of the Lorentz covariance of the equation with the use of the elongation formula for space volume simply leads just to Ott's formula (54) [40].

Let us also present simple and, in our opinion, convincing enough arguments in favour of Ott's formulation of relativistic thermodynamics. For this let us consider a material body that loses some heat energy due to radiation. In so doing, we are interested in the case when in the radiation process the state of body motion does not change. Then it is evident that the transformation formula for ΔQ (in this case it is an electromagnetic energy) should with necessity give the known relativistic equation [62]

$$\Delta Q = \Delta Q^*\gamma. \qquad (55)$$

Hence based on the second law of thermodynamics and the invariance of entropy, Ott's formula (54) simply follows.

2.4.4. The Lorentz-Covariant Theory of Gravitation [63,64]

Remind that relativistic generalization of the Poisson equation takes the form

$$\Box\, g^i = 4\pi G J^i. \qquad (56)$$

Here the 4-current mass density figures on the right; whence it follows that the relativistic gravitational potential should be also described by a 4-vector. The expression for g^i can be obtained by means of the Lorentz transformation of Newton's potential and is of the form [65]

$$g^i = -G\,\frac{MU^i}{U^i R_i}. \qquad (57)$$

Here M is the mass of a moving particle, U^i its 4-velocity, and R the retarded distance.

For the relativistic Newton force of gravity we have.

$$F^i = -mG^{ik}u_k, \qquad (58)$$

where G^{ik} is the gravitational field tensor, u^i the 4-velocity of a trial particle mass m.

In accordance with that G^{ik} is an antisymmetrical or symmetrical tensor for the gravitational field (in the absence of acceleration) we obtain

$$G^{ik} = -G\,\frac{Mc^2}{(U^i R_i)^3}\,(U^i R^k \mp U^k R^i). \qquad (59)$$

As a result, based on (59) for the relativistic Newton force we have

$$\mathbf{F} = -G\,\frac{mM\Gamma^{-2}\gamma}{R^2(1-\mathbf{Bn})^3}\,[\mathbf{n}(1+\beta\mathbf{B}) \mp \mathbf{B}(1+\beta\mathbf{n})], \qquad (60)$$

where $\mathbf{n} = \mathbf{R}/R$, $\beta = u^\alpha/u^0$, $\gamma = (1-\beta^2)^{-1/2}$, $\mathbf{B} = U^\alpha/U^0$, $\Gamma = (1-B^2)^{-1/2}$.

Certainly, we cannot avoid the question concerning the explanation of four known gravitational effects even despite sufficient persuasiveness of the above reasons. In this connection we note the following beforehand.

Three of the mentioned effects are in fact connected with changing (decreasing) the light velocity in the gravitational field. And one can say that we have here a certain analogy with the decrease of the light velocity in medium (due to electromagnetic interaction) according to the formula $c_n = c/n$, where n is the refractive index. In case of a (weak) gravitational field, as one would think, we have $n = 1 + 2\Phi/c^2$. The main difficulty is apparently to explain the displacement of Mercury's perihelion.

However, one must mark the following here. The use of eq. (60) instead of Newton's non-relativistic force when calculating the advance of Mercury's perihelion must lead to different from the presently accepted one. «Therefore the «residual» precession (if it exists at all) may be different from the presently accepted 43 seconds» [66].

2.4.5. High-Energy Physics

The Yukawa relativistic potential. Taking into account all peculiarities of the transition from Coulomb's potential to the Lienard — Wiechert one [67], we have (see, e.g., [53])

$$\Phi_\pi = -g_\pi \frac{\exp(-\mu R^i u_i)}{R^i R_i} \quad (61)$$

as a result of the Lorentz transformation of Yukawa's potential. Here μ is the pion mass, u^i the 4-velocity of nucleon, $\hbar = c = 1$. From (61) it follows that the pion field takes the form of a revolution ellipsoid streched in the motion direction. In particular, its distinctive sizes are $R_{\|} \sim 2\gamma\mu^{-1}$ and $R_\perp \sim \mu^{-1}$.

According to contemporary representations, hadrons consist of quarks which interact between themselves by gluon exchange, and so just quarks define in fact the behaviour of the «boundary region» of hadrons*. For the spinor field the Yukawa relativistic potential takes the form

$$\Phi_q = -g_q \frac{\sqrt{u^0 + 1}\,\exp(-\mu_q u^i R_i)}{\sqrt{2}\, u^i R_i}, \quad (62)$$

where μ_q is the mass of constituent quark.

*The pions, as one considers, are produced as a result of hadronization only at the very «boundary» of hadrons. As, on the other hand, for constituent quarks $\lambda_q \approx 0.7\ F$ (cf. with $\lambda_\pi \approx 1.4\ F$), then exactly quarks — these are to some extent «hidden parameters» — might mainly define the short-range action of nuclear forces.

According to the modern electroweek theory, weak interaction is conditioned by the exchange of $W^\pm$- and Z^0-bosons just as electromagnetic one is due to photon exchange. For this the weakness and a small radius of weak interaction is explained by that W- and Z-bosons are very heavy particles (m_W, $m_Z \sim 80$ GeV). The time component of the Yukawa relativistic (vector) potential [53] of weak interaction is

$$\Phi_W = -g_w \frac{u^0 \exp(-m_w u^i R_i)}{u^i R_i}. \quad (63)$$

Here a «weak charge» is defined by equality $g_W = G_F M^2$, where G_F is the Fermi constant and M the proton mass.

The explanation of the interaction cross-section growth at high energies [68] leans upon the indicated relativistic long-range effect of nuclear field. In particular, it leads to the effective growth of transverse sizes of hadrons defined in fact by the field equipotentials. One can say that hadrons «swell». This growth occurs only at the expense of nuclear field quanta having spin. At the same time the transverse sizes of the pion field, as it follows from (61), remain invariable with the increase of velocity. Therefore changing the transverse sizes of hadrons must be defined by the behaviour of the quark i.e., spinor field. The calculations using the Yukawa relativistic quark potential (63) indicate the growth of $R_\perp \sim (\ln\gamma)^{0.8}$. It must lead to the corresponding increase of cross-sections proportionally $(\ln\gamma)^{1.6}$.

At present time this result is, one can say, the only physical ground of the given experimental fact. It should be noted that we have here a definite analogy with the logarithmic growth of ionization losses at relativistic velocities (due to far collisions).

Relativistic rapprochement of interactions [69]. A significant growth of interaction potentials at the given distance from a «charge» (in the forward hemisphere relative to the motion direction) is the other side of the relativistic long-range effect. One can say that we have here the relativistic intensification of interactions. For this the difference in the spin structure of field quanta and mass influence lead to their different growth. And a slowed-up growth of the strong interaction in comparison with the electromagnetic and weak ones must lead to their rapprochment.

Based on (6), (63) and (62) for the ratios of the corresponding interaction energies, we obtain (in the «forward» direction, where the effect is maximum)

$$a_q^e \approx 10^{-3}\sqrt{\gamma}\exp(\mu R_{\|}/2\gamma), \quad (64)$$

$$a_q^w \approx 10^{-6}\sqrt{\gamma}\exp(-300\mu R_{\|}/\gamma), \quad (65)$$

where for simplicity $g_q \approx g_\pi$, $\mu_w \approx 600\,\mu$ and $\beta \simeq 1$. The calculated results are listed in tables 3 and 4. Analogous ratios a_π^e and a_π^w, where the strong interaction is described by the pion field (61), are presented there. As it seems, the rapprochement of electromagnetic and strong interactions must occur at $\gamma \simeq 2 \cdot 10^6$ that answers a proton energy of about $2 \cdot 10^3$ TeV. At the same time, if the behaviour of the strong interaction were defined by the pion field, than it would occur at $E_{es} \approx 2$ GeV and be discovered already in experiment. As to the rapprochement of the weak and strong interactions, it must occur at an energy of $E_{ws} \approx 10^{12}$ GeV. It is much larger than E_{es} but smaller than the energy in the model of «grand unification» that is estimated as $10^{14} \div 10^{16}$ GeV.

Table 3

γ	1	$2 \cdot 10^3$	10^4	10^5	$2 \cdot 10^6$
a_q^e	$4 \cdot 10^{-3}$	$3 \cdot 10^{-2}$	$7 \cdot 10^{-2}$	0.2	1
a_π^e	10^{-3}	1			

Table 4

γ	1	10^3	10^4	10^5	10^6	10^8	10^{10}	10^{12}
a_q^w	0	$3 \cdot 10^{-5}$	10^{-4}	$3 \cdot 10^{-4}$	10^{-3}	10^{-2}	0.1	1
a_π^w	0	10^{-3}	10^{-2}	0.1	1			

It is interesting to mark that for $\gamma \simeq 10^6$ at a distance ~ 1 Å the weak interaction reaches the quantity of the «static» electromagnetic one. As a result, the production of «weak» hydrogen atom (with neutron instead of proton) becomes in principle possible.

The invariant variable b_{ik} [70] used in relativistic nuclear physics is expressed through the relative 4-velocity U^i. Supposing $i = 1$ and $k = 2$, we have

$$b_{12} = 2(U^0 - 1), \quad |\mathbf{U}| = b_{12}(1 + b_{12}/4). \tag{66a,b}$$

The antiparticles existence is a peculiar result [71] of the Minkowski formula (41) that we rewrite in the form

$$E = p^0 c = mc\,\frac{dx^0}{d\tau} = mc^2\,\frac{dt}{d\tau}. \tag{41''}$$

As it follows from (41″), we have the motion of objects with negative energy $p^0 c = -|E|$ backward in time when reflecting the time $t = -|t|$. This is

completely equivalent to motion in the negative direction along the x-axis with momentum $p^1 = -|p_x|$ at mirror reflection. But the first picture is in absolute disagreement with our every-day macroscopic experience based on the existence of «time arrow». Since we pertain to the macroscopic world, we are not even capable of «seeing» a particle moving backward in time. We shall perceive this phenomenon an as «reinterpreted» one. Figuratively, this is like when the images of objects seen by the eye are turned upside-down (reinterpreted). So, according to the reinterpretation procedure, the initial and final states exchange what leads to chanding the sign of particle energy, momentum, charge and helicity. For example, we «see» positively charged positron instead of an electron, etc.

It should be emphasized that the well-known difficulties inherent in the Dirac vacuum (infinite charge, infinite negative energy and so on) are as a result removed. On the other hand, such questions as, say, the mass equality of particles and antiparticles, their life-times and so on (special proofs are need in the generally accepted approach) do not in general arise here.

As it follows from the above-said, the T-operation in essence leads us to antiparticles. Therefore, as it seems, T-invariance violation must result in the impossibility of the «introduction» of antiparticles itself, i.e., it should be accompanied by the violation of the law of lepton charge conservation (for example, in K_{l_3}-decays).

CONCLUSION

The interpretation of relativity theory generally adopted at the present time leans upon Einstein's definition of the moving rod length and operates in fact with instant (simultaneous) distances. However, these quantities are not the 4-vector components, i.e., they do not satisfy the demand of Lorentz covariance.

The modern completely covariant formulation, on the contrary, deals with the «prepared by nature» light or retarded (i.e., nonsimultaneous) distances and the covariant or radar length introduced on their basis. In its framework the former difficulties of the theory are solved. Among them are the Lewis — Tolman «paradox» of a level, the «problem 4/3», the non-invariance of charge of a current-carrying conductor and so on. The relativistic Doppler effect, Cherenkov radiation, etc., are direct experimental evidence in favour of this formulation.

Among the new results of theory we mark the following:

— the proofs of non-covariance of the contracted length, and the law of energy inertia;

— the effect of field relativistic long-range, the phenomenon of oscillation of an atom electric field, and the relation of the formation length with the field sizes of a moving charge;

— the united description of Cherenkov's radiation, transition radiation and radiation below the Cherenkov threshould, and the «Cherenkov bremsstrahlung»;

— the Lorentz-covariant theory of gravity;

— the Yukawa relativistic potential, the explanation of interaction cross-sections growth at high energies, and the phenomenon of interaction rapprochement at super-high energies, etc.

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