Invariance of the Time Deceleration Effect and Covariance of the Description in Minkovski Space

A. V. Genk

Scienific-Educationl Union "Earth and Universe", St. Petersburg, Russia
e-mail: gravitation@mail.admiral.ru

Abstract

In the present publication a covariant approach to the SRT allowing arbitrary, including non-inertial, frames of reference (FR) in the plane Minkowski space-time is developed. It was shown that the coordinate transformations of the FR of a moving mass (for the uniform motion — the generalized Galilee transformations) do not coincide with the symmetry group transformations — the generalized Lorentz-Poincare group. In particular, the time coordinate transformation may be arbitrary and has nothing to do with the Lorentz transformations. However the proper time is the Minkowski space invariant and does not depend on this arbitrariness. The proper time of a particle moving in an initial inertial Galilee FR I (connected with the galactic background) always runs slower than in the FR I, i. e. the time deceleration effect is absolute, but not relative. Upon comparison of the proper time of the particle and a laboratory, both moving in the Galilee FR I, the absolute velocity of the laboratory appears explicitly (for the Earth experiments it is the Sun velocity with respect to the Galaxy center). Thus this velocity may be experimentally detected by comparison of the tempos of two atom clocks moving in different directions in the experiments using a satellite.

1. Introduction. A covariant formulation of the SRT

The present paper is a direct (an immediate) continuation of our previous work [1] based on a covariant approach to the SRT formulated in the monograph [2] and is devoted to the further development of that approach. Some questions considered here are described in our paper [3] in a more detailed way. Certain aspects of the SRT covariant formulations had been considered earlier in [4–6], but a successive covariant construction of the theory is given only in [1–3]. Let us remind the basic postulates and some conclusions of [1].

The essence of the SRT, its basic and actually unique postulate can be formulated in the following way: *"all physical processes run in the unit Minkowski time-space, the geometry of which is pseudo-Euclidean"*. In other words, we postulate that in the whole space there is a physical frame of reference (FR) called an inertial (Galilee) one in which the interval between events of this space is written as

$$ds^2 = c^2 dT^2 - dX^2 - dY^2 - dZ^2. \tag{1}$$

In general, in the Minkowski space-time any FR in which the interval 1 has the general form

$$ds^2 = g_{ik} dx^i dx^k \tag{2}$$

and which satisfies the allowance conditions $g_{00} > 0$; $g_{\alpha\beta} dx^\alpha dx^\beta < 0$ is allowed.

The curvature tensor becomes zero identically: $R_{iklm} = 0$ in any FR of the Minkowski space, including non-inertial (accelerated) one. The transformations connecting FR's of the real moving bodies (particles of matter) with the initial inertial Galilee FR 1 can be either linear or non-linear ones. The first ones (which are always non-orthogonal ones [3] for the real bodies and, therefore, not coinciding with the Lorentz transformations!) form a so-called generalized inertial FR (with non-orthogonal axes t, x) the metrics of which has the off-diagonal part $g_{0i} \neq 0$, the second ones give in turn the non-inertial (accelerated) FR's (also with a nondiagonal metrics). The particular case of the generalized inertial FR is the FR connected with the inertial one 1 by the classic Galilee transformation: $X = x + Vt$; $t = T$, and corresponding to rotation of the axis T with fixed orientation of the axis X. The properties of the generalized inertial FR's are explicitly considered in [1–3].

Let us pass from Galilee's coordinates $X^i = (X, Y, Z, T)$ with the metric 1 to coordinates $x^i = (x, y, z, t)$ by arbitrary linear transformation. This transformation is equivalent up to a space axis rotation to a transformation in plane X, T:

$$X = ax + bt; \quad T = qx + pt; \quad Y = y; \quad Z = z. \tag{3}$$

Substituting (3) in (1), in coordinates x^i the metric gets the form:

$$ds^2 = c^2 g_{00} dt^2 + 2cg_{01} dt dx + g_{11} dx^2 - dy^2 - dz^2, \tag{4}$$

where $g_{00} = p^2 - b^2/c^2$; $g_{01} = c(pq - ab/c^2)$; $g_{11} = c^2q^2 - a^2$. The transformation 3 describes the rotation of the axes x, t in the plane X, T, with after the rotation the axis x can be not orthogonal to the axis t, i.e. x and t rotate on angles, which may differ. The metric 4 gives *a generalized inertial frame of reference* in the SRT. The Lorentz transformations are a particular case of the general linear transformations 3, corresponding to the choice $g_{00} = 1$, $g_{01} = 0$, $g_{11} = -1$ in 4. Hence, the metric 4, in contrast to (1), is not forminvariant with respect to the Lorentz transformations.

Let us consider a rotation of axis t without changing of the x orientation as particular case of the transformation 3. It is the classic *Galilee transformation*:

$$X = x + v_0 t; \qquad T = t, \tag{5}$$

corresponding to the choice of parameters in 3 as $p = a = 1$; $q = 0$; $b = v_0$. Thus, the metric 4 get the form:

$$ds^2 = \left(1 - \frac{v_0^2}{c^2}\right) c^2\, dt^2 - 2v_0\, dt\, dx - dx^2 - dy^2 - dz^2. \tag{6}$$

The metrics of the inertial (Galilee) FR 1 is forminvariant with respect to the classic Lorentz-Poincare transformation group L^i_m. The metrics of the generalized inertial FR is that with respect to the so-called generalized inertial Lorentz-Poincare group [1] connected with the classic one by the relation

$$\hat{L}^n_k x^k = \left[B^n_i L^i_m (B^{-1})^m_k\right] x^k. \tag{7}$$

where B^i_k is the matrix of the linear (non-orthogonal) transformations forming the generalized inertial FR $x^i = B^i_k X^k$. The transformations (7) are orthogonal [3] but connect the number of non-orthogonal FR's with the same nondiagonal metrics.

In the particular case of the Galilee transformation with metric 6 the group of transformations, keeping the metric 6 forminvariant, takes the form:

$$\begin{aligned} x_{\text{н}} &= \frac{1}{\sqrt{1-V^2/c^2}}\left\{\left(1+\frac{uV}{c^2}\right)x_{\text{c}} + \left(1-\frac{u^2}{c^2}\right)Vt_{\text{c}}\right\} \\ t_{\text{н}} &= \frac{1}{\sqrt{1-V^2/c^2}}\left\{\frac{V}{c^2}x_{\text{c}} + \left(1-\frac{Vu}{c^2}\right)t_{\text{c}}\right\}. \end{aligned} \tag{8}$$

At $u = 0$ 8 coincides with the Lorentz transformation, naturally.

Finally, the metrics of any noninertial FR is forminvariant with respect to the generalized noninertial Lorentz-Poincare group [1] having the form in symbols

$$\mathcal{L}^n(x^k) = f^n\left[L^i_m(f^{-1})^m(x^k)\right], \tag{9}$$

where f^n are non-linear functions of a transformation forming a noninertial FR.

Therefore the transformations leaving some metrics (2) forminvariant are also those of symmetry (invariance) group of all physical laws written in this metrics. These transformations of the symmetry group cannot be associated with the real body motion, they are only realized as transformations of abstract 4-motions (changing of the point arithmetization) in the Minkowski space with a fixed physical body as the origin [3]. Particularly, in the generalized inertial FR the parameter V of the symmetry group (7) (of the generalized inertial Lorentz one) is not connected with the velocity V_0 of the uniform motion of the real body in the inertial Galilee FR (see fig. 1). In spite of this the physical manifestation of this generalized Lorentz symmetry of the space-time and all the laws of nature are universal and fundamental — it accounts for all known relativistic effects and relations for physically measurable values in any FR, as well as the conservation laws.

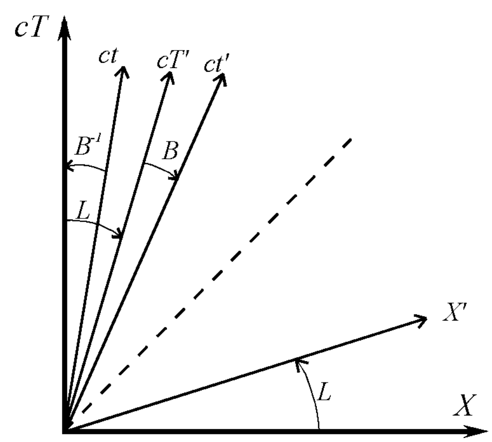

Figure 1: The geometrical sense of the transformations of the generalized inertial Lorentz group (7) for the case when B^i_k is classic Galilee transformations. The axis t turns by "angle" BLB^{-1}, the axis X does only by "angle" L, axes t', X' remain non-orthogonal, and the parameter V of the Lorentz rotation L is arbitrary.

From this viewpoint it is naturally to generalize the symmetry groups on the superluminal domain $V > c$ (because V is the velocity of abstract 4-motions, but not of real particles motion of any kind) manifesting itself as the charge or mirror space symmetry (concerning this see [9] and bibliography listed there).

The existence of the metric forminvariance group in any allowed FR (inertial or not) expresses the generalized relativity principle [1, 2].

As far as the Minkowski space-time geometry doesn't vary under *any* FR transformation allowed and remains a plane pseudo-Euclidean one, in the *noninertial* FR there is a group of the coordinate transformations leaving forminvariant the metric tensor. Thus, in the pseudo-Euclidean space-time *a generalized relativity principle* is valid (first formulated in [2]; our formulation is almost the same):

> *"Any physical frame of reference, inertial (including generalized) or noninertial one, being taken, one can always find the infinite number of other FR's, in which all physical processes run uniformly with the initial FR (i.e. absolutely physically equivalent, identical to the initial one), so that no one have any experimental possibility to find out, which FR from this infinite set we are in".*

This infinite set of FR's we shall call an **"equivalence class"**. Let us emphasize that any physical process allows to find simply out, weather we are in an inertial or noninertial FR. But no any physical experiment can allow to do so for the FR's from one equivalence class.

Note yet a very important circumstance [6]. *The absolute* physical equivalence (identity) takes only place in the frame of *one equivalence class* of FR's, i.e. connected by the only transformation group (for example, the inertial Galilee FR's connected by the Lorentz group or the generalized inertial FR's 4, done by one of the generalized group 7, with B^i_k being chosen). If the groups are *different* (i.e. the equivalence classes differ), there is no absolute physical equivalence (identity) of such FR's, even if the two are inertial. In this case the relativity principle of inertial motions is *not applicable* in its usual sense (i.e. in that of indistinguishableness of the inertial FR's). For instance, although the Galilee 1 and generalized 6 FR's are inertial (i.e. all physical laws expressed in terms of the physically measurable values have the same form), they are not identical to each other, and this has an important significance (see below par. 7). About relativity of the inertial motions at all one can speak in the sense of the law form coincidence in all inertial FR's, and not in that of their indistinguishableness or identity.

This principle states [1] the absolute physical equivalence (identity) of the FR's inside *an equivalence class*, i. e. those connected by a symmetry group. Upon any motion of a real physical body, which for certain, had accelerated for some time in the initial inertial Galilee FR, the equivalence class connected with the body inevitably undergoes modification, even in the body goes on moving uniformly after all. Thus the generalized inertial FR's are not already physically identical to the initial inertial Galilee FR, because they belong to another than Lorentz equivalence class (although all physical laws expressed by measurable values have the same form like in the Galilee FR). The proper time (the invariant of the Minkowski 4-space — the length of a world line!) runs in such FR's slower than in the initial Galilee FR, i.e. the time deceleration effect is absolute, but not relative [1].

2. Uniformly accelerated frames of reference and the time transformation

Let a relativistic uniformly accelerated FR with the coordinates (x, t) move without initial velocity along the axis X of an inertial Galilee FR with the coordinates $(X,\, T)$ and at $t = 0$ their origins coincide. Then the coordinate transformation formulas x have the form [1, 2]:

$$x = X - \frac{c^2}{w}\left[\sqrt{1 + \frac{w^2T^2}{c^2}} - 1\right]. \tag{10}$$

The motion law, i. e. the transformation to FR stringently connected with a uniformly accelerated moving body, is already defined, it means that the space coordinate transformation is already fixed (up to rotations and shifts). The covariance of the SRT description finds here its manifestation in arbitrariness of the dependence $t = t(T, X)$ of the time coordinate (if only it doesn't violate the allowance conditions of arbitrary metrics (2).

In [1] we considered the simplest possible dependence $t = T$. In this case, substituting (10) and $t = T$ into the metrics (1) gives the expression of the metrics of a uniformly accelerated FR

$$ds^2 = \frac{c^2\, dt^2}{1 + w^2t^2/c^2} - \frac{2wt\, dt\, dx}{\sqrt{1 + w^2t^2/c^2}} - dx^2 - dy^2 - dz^2. \tag{11}$$

In [1] from the general expression of the noninertial Lorentz-Poincare group (9) an explicit form of this group transformations for (10) and $t = T$ was obtained. Now we consider another time transformation

$$t = \frac{c}{w}\,\mathrm{Arsh}\,\frac{wT}{c}. \tag{12}$$

The transformation (12) is single out by the fact that the right part of (12) coincides with the proper time of a uniformly accelerated moving particle

$$\tau = \int\limits_0^T dT\sqrt{1 - v^2/c^2} = \frac{c}{w}\,\mathrm{Arsh}\,\frac{wT}{c}. \tag{13}$$

Let us remind that expression in integral (13) follows not from the Lorentz transformations, but from the Galilee interval form (1) written for any moving particle [1]. It is the Minkowski 4-space invariant.

The inverse transformation to (10), (12) has obviously the form

$$X = x + \frac{c^2}{w}\left[\mathrm{ch}\,\frac{wt}{c} - 1\right]; \qquad T = \frac{c}{w}\,\mathrm{sh}\,\frac{wt}{c}. \tag{14}$$

Substituting (14) in (1), we find the metrics of the noninertial FR connected with a uniformly accelerated moving body by the (10), (12):

$$ds^2 = c^2dt - 2c\,\mathrm{sh}\left(\frac{wt}{c}\right) dxdt - dx^2 - dy^2 - dz^2. \tag{15}$$

At $t = 0$ the metrics (15) naturally coincides with the Galilee one. Note that in (15), in spite of (11), we have $g_{00} = 1$. The time coordinate in (12) was defined so as to make the dependence on t vanishe.

Let us find the explicit form of the generalized noninertial Lorentz group (9) transformations leaving the metric (15) forminvariant. Using (10), (12), (14) we obtain from (9) [3]:

$$t_{\text{н}} = \frac{c}{w}\,\text{Arsh}\left\{\frac{w}{c}\frac{\left[\frac{c}{w}\,\text{sh}\,\frac{wt_c}{c} - \frac{v}{c^2}\left(x_c + \frac{c^2}{w}\left(\text{ch}\,\frac{wt_c}{c} - 1\right)\right)\right]}{\sqrt{1 - v^2/c^2}}\right\}. \tag{16}$$

As in the case $t = T$ and metric (11) [1], the formulas (16) for the case $t = \tau$ (12) were first obtained in [2], but in a much more complicated way — by solving a system of partial differential equations. We in turn obtained (16) from the elementary and obvious expression of the noninertial Lorentz group (9), from which its connection with the classic Lorentz group is immediately seen. Therefore the transformations (16) leaving the metrics (15) forminvariant are those of all physical laws written in this metrics. As was noted above (par. 1), the symmetry group transformations (in this case (16)) cannot connect the moving mass FR's, they are only abstract 4-motion transformations in the Minkowski space. The group parameter V in (16) which by the very sense of derivation of (16) from (9) is the Lorentz group parameter in the inertial Galilee FR is not also the velocity of any moving body which the number of FR's are connected with. This is the velocity of abstract motions in the FR equivalence class (16) with a fixed reference body which moves in turn in the inertial Galilee FR (1) in a definite way, in this case it is uniformly accelerated.

3. The invariance of the proper time and the arbitrariness of the time coordinate

Just as we considered the "clock paradox" in [1] (see also [2, 3]), we will consider the clock II motion in an inertial Galilee FR (fig. 2) within two periods—the initial one 1 of the uniformly accelerated motion and the consequent inertial one 2. In [1], following [2], for the period 1 we used the simplest time transformation $t = T$. There we also noted that using of another time transformation, for example (12), would not change the result [3]. In view of a great significance of this example for understanding of the covariant essence of the SRT we will show it here explicitly.

We suppose that the FR II coordinate transformations at the part 1 are given by the formulas (10), (12), (14). To begin, let us consider the clock I motion in the FR II. This clock is at the point $X = 0$ (FR I), and from (14) we immediately obtain its motion law in the FR II (of cause it can be obtained formally from the equation of geodesic motion in the metrics (15)): $x_I = \frac{c^2}{w}\left[1 - \text{ch}\,\frac{wt}{c}\right]$. In the FR II the clock I moves uniformly accelerated in the negative direction. Thus, for the proper time (the world line length) of the clock I at the noninertial part 1, moving in the FR II according to the law of geodesic motion, we find from the general formula (see [1]) the expressions for the metrics (15):

$$d\tau = dt\left[g_{00} + \frac{2}{c}g_{01}\left(\frac{dx}{dt}\right) - \frac{1}{c^2}\left(\frac{dx}{dt}\right)^2\right]^{1/2} = dt\cdot\mathrm{ch}\left(\frac{wt}{c}\right). \tag{17}$$

From (17) with regard to (14) we have $\tau_1 = \dfrac{c}{w}\,\mathrm{sh}\left(\dfrac{wt_1}{c}\right) = T_1$; i. e. the clock I proper time at the part 1, calculated in the FR II either upon dependence $t = T$ [1] or upon $t = \tau$ (12), is the same (and coincides with its value in the FR I), as it should be in accordance with the general property of the interval invariance.

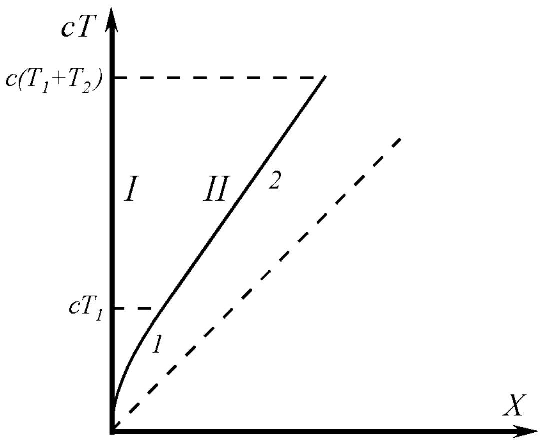

Fig. 2.

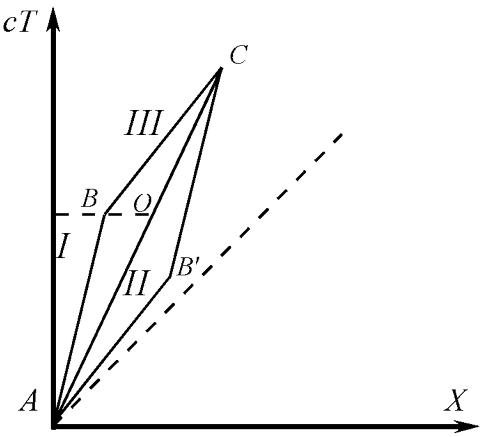

Fig. 3.

The clock II reposes in the metrics (15) and its proper time at the part 1 equals

$$\tau_1' = \int\limits_0^{t_1}\sqrt{g_{00}}\,dt = t_1 = \frac{c}{w}\,\mathrm{Arsh}\,\frac{wT_1}{c}. \tag{18}$$

The expression (18) coincides both with the result for the dependence $t = T$ and with the proper time (13) calculated in the FR I. Formally, changing of the time dependence in (15) as compared with (11) means just changing of variables in the integral $\tau = \int d\tau$, that always gives the same final result.

Investigation of the part 2 of the clock I *inertial* motion is more rich in content. At the moment $T = T_1$ (by the clock I), or $t = t_1 = (c/w)\,\mathrm{Arsh}\,(wT_1/c)$ (by the clock II) the clock II begins to move uniformly with the velocity (in the FR I) $v_0 = \frac{wT_1}{\sqrt{1+w^2T_1^2/c^2}}$. At the same moment the noninertial metrics (15) has the only component not coinciding with the Galilee one (1):

$$g_{01}(t_1) = -\,\mathrm{sh}\,\frac{wt_1}{c} = -\frac{wT_1}{c} = -\frac{v_0/c}{\sqrt{1-v_0^2/c^2}}. \tag{19}$$

Thus, because of the metric continuity in time [1], from (19) we obtain that on the part of the clock II *inertial* motion the FR II metrics has also the form differing from the Galilee one (1):

$$ds^2 = c^2dt^2 - \frac{2v_0\,dtdx}{\sqrt{1-v_0^2/c^2}} - dx^2 - dy^2 - dz^2. \tag{20}$$

The metrics (20) belongs to another (than the Lorentz one) *class of equivalence* [1], namely to that of generalized inertial metrics forminvariant with respect to the generalized inertial Lorentz-Poincare group (7). The FR on the inertial part with metrics (20) is connected with the Galilee one (1) by some linear transformation (3).

In the case of the simplest dependence $t = T$ at the part 1 the transformation (3) could be easily found — it coincides with the classic Galilee transformation $X = x + v_0 t$; $t = T$. For the chosen dependence $t = \tau$ (12) at the part 1 we need to use a more formal method of the transformation (3) determination. Using expressions [1] for the generalized inertial metric components (here it is (20)) through the transformation (3) coefficients, gives the following equation system for their definition

$$\begin{cases} g_{00} &= p^2 - \dfrac{b^2}{c^2} = 1; \qquad g_{11} = c^2q^2 - a^2 = -1; \\ g_{01} &= c\left(pq - \dfrac{ab}{c^2}\right) = -\dfrac{v_0/c}{\sqrt{1 - v_0^2/c^2}}. \end{cases} \tag{21}$$

For the unambiguous solution of (21) one more equation is needed. It should express the fact of uniform (inertial) motion of the reference body of the FR II (at the point $x = 0$) with the velocity v_0 in the FR I. It is easy to see that the required equation has the form [3] $b/p = v_0$. The solution of (21) corresponding to codirectedness of the axes X and x, T and t is

$$x = X - v_0 T; \qquad t = T\sqrt{1 - v_0^2/c^2}. \tag{22}$$

The transformation of the type (22) could be called a *"generalized Galilee one"*, in contrast to the usual classic one (in which $t = T$) the dependence between t and T in (22) changed. Choose we on the noninertial part 1 another (than $t = T$, or $t = \tau$ (12)) time coordinate transformation, the dependence between t and T in (22) would also change.

With regard to (22) in the generalized inertial metrics (20) the proper time of the clock II (reposing in the FR II) is defined by the expression

$$\tau_2' = \int\limits_{t_1}^{t_1+t_2} \sqrt{g_{00}}\, dt = t(T)\Big|_{T_1}^{T_1+T_2} = T_2\sqrt{1 - v_0^2/c^2}, \tag{23}$$

i. e. we really obtained for τ_2' the same formula as for the dependence $t = T$, which equals to T_2', i. e. to the clock II proper time in the Galilee FR I (the length of the world line is the Minkowski space invariant). Comparing (22) with (23), we see that the time coordinate transformation at the part 2 also can be shortly written as in (12), (13) in the form $t = \tau$, where τ is the proper time.

Let us consider now the clock I movement in the FR II during the period of the clock II uniform motion with the metrics (20). Supposing $X = 0$ (or $X - X_0 = 0$) in (22) we obtain the clock I motion law in the FR II (it is the motion along the geodesics of the metrics (20)): $x_I(0, T) = -v_0 T = -\frac{v_0 t}{\sqrt{1 - v_0^2/c^2}}$. From this equation we have for the clock I *coordinate* velocity in the FR II: $\frac{dx_I}{dt} = -\frac{v_0}{\sqrt{1 - v_0^2/c^2}}$, i. e. for the dependence $t = \tau$ the clock I coordinate velocity is not already equal to $-v_0$, as it was for $t = T$. It can be arbitrarily great (not of the physical velocity—see below par. 4). With regard to (20) for the clock I proper time in the FR II we find

$$\tau_2 = \int\limits_{t_1}^{t_1+t_2} dt \left[g_{00} + \frac{2}{c} g_{01} \left(\frac{dx_I}{dt} \right) - \frac{1}{c^2} \left(\frac{dx_I}{dt} \right)^2 \right]^{1/2} = \frac{t}{\sqrt{1 - v_0^2/c^2}} \Big|_{t_1}^{t_1+t_2} = T_2. \tag{24}$$

Thus, τ_2 calculated in the FR II does coincide with the clock I proper time in the FR I, as it should be.

So, a straightforward calculation showed that this or that choice of the time coordinate transformation at the uniformly accelerated movement part of the trajectory ($t = T$ in [1] or $t = \tau$ in the present paper) leads both to the correspondent altering of the generalized inertial metric (20) at the uniform motion part and to the change of the transformation (22) connecting this FR with the Galilee one. However the proper time of the both clocks I and II remains invariable (invariant) upon calculating in the FR's I and II, according to the general property of the world line length invariance in the Minkowski space [1, 3] with respect to any allowed coordinate transformations*.

Independent of the chosen time coordinate definition the proper time of the moving clock II is always less than that of the clock reposing in the Galilee FR of the clock I at both the noninertial and uniform (inertial) motion part of the clock II. Thus, the proper time deceleration of the clock II undergone an acceleration at the part 1 (even if the part 1 arbitrarily short in comparison with the part 2) is an absolute effect, but not relative [1, 3], and independent of the time coordinate definition.

4. Physical and coordinate values

As known [1, 2, 3], constructing the covariant SRT one should exactly distinguish a *coordinate* (in some sense formal-mathematical) velocity dx/dt of a particle and its *physical* (experimentally measurable) one. The latter is defined as the ratio of the physical distance and time:

$$V_\Phi \equiv dl/d\tau; \qquad ds^2 \equiv c^2\, d\tau^2 - dl^2, \tag{25}$$

where

$$\begin{aligned} d\tau &= \sqrt{g_{00}}\, dt + g_{0\alpha}\, dx^\alpha / c\sqrt{g_{00}}; \\ dl^2 &= (-g_{\alpha\beta} + g_{0\alpha} g_{0\beta}/g_{00}) dx^\alpha dx^\beta \equiv \kappa_{\alpha\beta} dx^\alpha dx^\beta. \end{aligned} \tag{26}$$

The coordinate and physical velocities always concur only in the inertial Galilee FR I with the metrics (1).

Let us first consider the simplest dependence $t = T$ at the part of the inertial motion. In this case the metrics in the FR II connected with the FR I by the usual Galilee transformation has the form [1, 3] (6).

*Strictly speaking, our aim in [1, 3] was not so much to prove this invariance (as far as this fact is a fundamental property of the Minkowski space) as to show with the help of the concrete instances how the invariance and the noninertial part of trajectory inevitably change the FR equivalence class of the clock II at this part. The FR of the clock II turns out to be connected at it with the initial Galilee one (1) not by the Lorentz transformation, but the Galilee one. This is what provides the proper time invariance.

From (26), (6) we then have (for motion along the axis x):

$$d\tau = dt\sqrt{1 - v_0^2/c^2} - \frac{v_0/c^2}{\sqrt{1 - v_0^2/c^2}}dx; \qquad dl = \frac{dx}{\sqrt{1 - v_0^2/c^2}}. \tag{27}$$

Substitution (27) in the definition (25) gives the dependence between the physical and coordinate velocities of the particle in the metrics (6):

$$V_{\Phi}^{x} = \frac{dl}{d\tau} = \frac{(dx/dt)}{1 - \dfrac{v_0^2}{c^2} - \dfrac{v_0}{c^2}\left(\dfrac{dx}{dt}\right)}. \tag{28}$$

The clock I coordinate velocity in the FR II is [1] $dx_I/dt = -v_0$ (it is the geodesic motion in the metrics (6)). Substituting this value in (28) we find that the clock I physical velocity V_Φ turns also out to be equal to $-v_0$. Therefore for the simplest dependence $t = T$ the clock I physical and coordinate velocities coincide in the FR II (although for any other coordinate velocity differing from $-v_0$ the physical (28) and coordinate velocities will not do; particularly, for the light [2, 3] $dl/d\tau \equiv c$, and $|dx/dt| = c \pm v_0$ in the metric (6).

Let us now consider the dependence $t = \tau$ (12). As it was shown in [3] $(dl/d\tau)_I = -v_0$, what is equal to the clock I physical velocity at the last moment of the acceleration. Thus, at this moment t_1 in the FR II both physical and coordinate velocities of the clock I are *continuous* (in spite of the erroneous statement in [8]), although they can differ from each other (as, for example, upon dependence $t = \tau$). The continuity of both kinds of velocities follows from that of the metric tensor at the moment $t = t_1$.

Let us briefly consider now the law of the particle physical velocity composition (see [2, 3] for details). Let two particles uniformly move along the axis X in the initial inertial Galilee FR I — the first one (connected with the FR II) with the velocity v_0, another one — with the velocity v_1. As it was shown in [3] the generalized inertial FRs of the particles 1 and 2 are connected with the Galilee one not by the Lorentz transformation, but by the generalized Galilee one. Nevertheless the *physical* velocities of the particles are subjected to the Lorentz law of the velocities composition. It is manifestation of the pseudo-Euclidean structure of the Minkowski space-time, or, in the other words, of the symmetry of the space-time and that of all laws of nature symmetry with respect to the generalized Lorentz-Poincare group [1]. The coordinate transformations connecting the FR I and II of the particles 1 and 2 have in turn no relation to the Lorentz ones (the transformations of the law symmetry group and those of the moving real bodies FRs are absolutely different concepts).

The necessity to differ the coordinate and physical values in the non-Galilee metric concerns not only the velocity, but has an universal character. Namely, every coordinate 4-vector a^i (4-tensor a^{ik}) is associated with a physical 4-vector $A^{\overline{\jmath}}$ (4-tensor $A^{\overline{\jmath p}}$) according to the rule [2]:

$$A^{\overline{\jmath}} = \lambda_i^{\overline{\jmath}} a^i; \qquad A^{\overline{\jmath p}} = \lambda_i^{\overline{\jmath}}\lambda_k^{\overline{p}} a^{ik}, \tag{29}$$

where $\lambda_i^{\overline{\jmath}}$ — 16-component value (tetrad) expressed via the metrics. In particular, the expressions (25), (26) can be written in the form $d\overline{X}^j = \lambda_i^{\overline{\jmath}} dx^i$, where $d\overline{X}^0 \equiv c\,d\tau$; $dl^2 = (d\overline{X}^j d\overline{X}^k)\delta_{ik}$. Using (25), (26), it is easy to show [2] that the non-zero components of the tetrad equal in this case:

$$\lambda_i^{\overline{0}} = \frac{g_{0i}}{\sqrt{g_{00}}}; \quad \lambda_1^{\overline{1}} = \sqrt{\kappa_{11}}; \quad \lambda_2^{\overline{2}} = \sqrt{\kappa_{22}}; \quad \lambda_3^{\overline{3}} = \sqrt{\kappa_{33}}. \tag{30}$$

For the generalized inertial FR with the metrics (6) we have in (30) $\lambda_1^{\bar{1}} = 1/\sqrt{1 - v_0^2/c^2}$; $\lambda_2^{\bar{2}} = \lambda_3^{\bar{3}} = 1$, and $\lambda_i^{\bar{0}}$ is given by (6).

To illustrate using of (29) let us obtain the transformation formulae for the light frequency of a monochromatic flat wave upon the passing to the generalized inertial FR II of the uniformly moving mass particle. It is connected with the initial inertial Galilee FR I by the Galilee transformation: $X = x_{II} + v_0 t,\ T = t$.

In the FR I the wave 4-vector components equal $k_I^i = \left(\frac{\omega_0}{c}; \frac{\omega_0}{c}\mathbf{n}\right)$, where $\mathbf{n}$ is a unity vector normal to the wave front, ω_0 — the light frequency of the source reposing in the FR I. Upon the Galilee transformation the *coordinate* components of the 4-vector will obviously be equal to

$$k_{II}^0 = k_I^0; \qquad k_{II}^1 = \frac{1}{c}\frac{\partial x}{\partial T} k_I^0 + \frac{\partial x}{\partial X} k_I^1 = \frac{\omega_0}{c}\left(\cos\alpha - \frac{v_0}{c}\right), \tag{31}$$

where α is the angle between $\mathbf{n}$ and $\mathbf{v}_0$ in the FR I with accordance to (29). The *physical* components are $K_{II}^{\bar{j}} = \lambda_i^{\bar{j}} k_{II}^i$. In particular, for the zero-components by (6), (31), (32) we have [3]*

$$\frac{\omega}{c} = K_{II}^{\bar{0}} = \lambda_i^{\bar{0}} k_{II}^i = \frac{g_{0i}}{\sqrt{g_{00}}} k_{II}^i = \frac{\omega_0}{c} \frac{\left(1 - \frac{v_0}{c}\cos\alpha\right)}{\sqrt{1 - v_0^2/c^2}}. \tag{32}$$

Thus, for the physically measurable frequency in the FR II we obtained the well-known relativistic formula for the Dopler effect. It was made on the basis of the Galilee, but Lorentz, transformations, just as it was when we obtained Lorentz law of the physical velocities composition [3].

5. The relative motion of two generalized inertial FR's

Till now we considered the proper time deceleration of one particle moving in the inertial Galilee FR I and showed that this deceleration is absolute and doesn't depend on the time coordinate definition at the inertial part of the trajectory. Let now there be 2 particles moving from a 4-point in the FR I with *different* velocities v_0 and v_1 (in the FR I), i. e. there are three physical FR's: the initial Galilee one (the FR I), the FR II (of the clock II), moving with the velocity v_0, and finally the FR III (of the clock III) moving with the velocity v_1. Which is the relation between the two clocks' tempos? As it was shown in [1] and in par. 3, the clock II and III accelerated part (inevitable for any mass particle) is of principle importance, even if the length of the correspondent part of the world lines is negligibly small compared to the inertial part length. The noninertial parts change inevitably the metrics in the FR's II and III. The metrics in them belongs to another equivalence class differing from the Lorentz one — to that of the generalized inertial metrics [1]. Is the simplest dependence $t = T$ chosen, for the connection between the FR II and III coordinates and the initial inertial FR I we have the classic Galilee transformation, but not the Lorentz one: $X = x_{II} + v_0 T$; $X = x_{III} + v_1 T$, giving the

*The expression for the physical x-component leads immediately to the relativistic formula for aberration [3]: $\frac{w}{c}\cos\alpha' \equiv K_{II}^{\bar{1}} = \lambda_i^{\bar{1}} k_{II}^i$, and from (30)–(32) we have: $\cos\alpha' = (\cos\alpha - v_0/c)/(1 - v_0\cos\alpha/c)$

metrics of type (6). Further we will neglect the length of the noninertial parts of the clock II and III trajectories.

Let us consider the process, when the clock III in the FR II moves at first away from the clock II, and then meets it again. In the inertial Galilee FR I such a process is drawn as a triangle of the world lines (fig. 3) ABC and $A'B'C'$, depending on the clock III motion direction with respect to the clock II. The clock II and III proper time decelerates in comparison with the clock I (the deceleration effect is absolute, see [1] and par. 3), no matter which velocities the clocks II and III ever move with. What is the relation between them, but not with the clock I?

It is easy to see (fig. 3) that there are two possibilities: at the part $AB = B'C'$ the clock III moves in the FR I slower (in the sense of the motion velocity) than the clock II ($0 < v_1 < v_0$), and at the part $BC = AB'$ — *quicker* than the clock II correspondingly ($v_2 > v_0$, v_2 is the clock III velocity in the FR I at the part BC). In accordance with this, an absolute proper time deceleration (the clock rate) by $\sqrt{1 - v^2/c^2}$ times* in comparison with the clock I results at the part $AB(= B'C)$ in the *acceleration* of its rate with respect to the clock II ($|AO| < |AB|$), and at the part $BC(= AB')$ — in the *deceleration* ($|OC| > |BC|$) correspondingly. What would the comparison of the readings of the clocks II and III at the meeting point C show? It is naturally to expect that amounting — at the point C — we will always have the clock III proper time deceleration in comparison with the clock II. It is confirmed by the following theorem.

Theorem 1 (on a triangle property in the Minkowski space-time) *The sum of the two time-like world lines AB and BC of a mass particle moving in the inertial Galilee FR I with the velocities v_1 and v_2 correspondingly is always less than the straight world line length AC of a particle moving with the velocity v_0 (in the FR I) and linking the beginning of the first world line (point A) and the end of the second one (point C).*

Proof. See [3].

Next Theorem 2 follows directly from Theorem 1

Theorem 2 (About the straight line extremity in the Minkowski space-time) *a) The length of the time-like world straight line of the mass particle uniformly moving in the inertial Galilee FR between arbitrary 4-points A and C is always* **greater** *than the length of any curved world line ABC of a particle moving arbitrarily between the same points.*

b) Among the time-like world lines connecting the 4-points A and C the straight line (in the inertial Galilee FR) has the maximal length.

Proof. See [3].

Note also, that upon the clock paradox analysis in [1] we have mentioned the obvious fact that the straight world line length in the FR I is always greater than that of any curve "because of the Minkowski space pseudo-Euclidean structure" [1]. But there we

*Let us repeat that this deceleration is not the sequence of the Lorentz transformations to the FR's II and III (because these generalized inertial FR's are connected with the Galilee one by the Galilee transformation, but not by the Lorentz one!), but of the pseudo-Euclidean structure of the Minkowski space [1], i. e. of the interval form (1).

kept in mind the straight line coinciding with the axis cT (in the FR I) — in this case the mentioned property does follow from the interval expression in the FR I $ds^2 = c^2dT^2 - dX^2$. However in Theorem 2 this property is proved for any straight line AC, not coinciding with the axis cT, and thus it isn't so obvious as in the simplest case of the line cT*. In the standard, "inertial-Lorentz" constructing of the SRT ignoring a covariant essence of the theory and the concept of the generalized inertial FR the strict consideration of Theorem 1 (although their sense is sometimes mentioned in literature) and 2 is impossible at all—any world line triangle leads immediately to the clock paradox [1, 2] — the calculations in the FR's I and II is "relative" (symmetrical), and non-inertial FR's are regarded already outside of the SRT frame.

6. A moving one-dimensional oscillator

Let us once more consider the process drawn on fig. 4 and express the particle III proper time at the parts AB and B via the physical velocity of the particle in the FR II. We have:

$$\begin{aligned} \tau_{AO} &= T_1\sqrt{1 - v_0^2/c^2}; \qquad \tau_{OC} = T_2\sqrt{1 - v_0^2/c^2}; \\ \tau_{AB} &= T_1\sqrt{1 - v_1^2/c^2}; \qquad \tau_{BC} = T_2\sqrt{1 - v_2^2/c^2}. \end{aligned} \tag{33}$$

The particle III velocity in the FR I (v_1 and v_2; let us remind, that in the inertial Galilee FR I the coordinate and physical velocities always coincide—par. 4) is connected with the particle II velocity in the FR I (v_0) and the particle III physical one in the FR II $v_1^\Phi > 0, v_2^\Phi < 0$ by the relativistic law of the velocity composition (30).

$$v_1 = \frac{v_0 + v_1^\Phi}{1 + \dfrac{v_0 v_1^\Phi}{c^2}}; \qquad v_2 = \frac{v_0 - |v_2^\Phi|}{1 - \dfrac{v_0 |v_2^\Phi|}{c^2}}. \tag{34}$$

In the non-relativistic limit for the first order with respect to v^2/c^2 the expressions (33), (34) have obviously the form (for simplicity we assume $v_1^\Phi = |v_2^\Phi| = v^\Phi$):

$$\begin{aligned} \tau_{AB} &= \tau_{AO} - T_1\left(\frac{v_0 v^\Phi}{c^2} + \frac{{v^\Phi}^2}{2c^2}\right), \\ \tau_{BC} &= \tau_{OC} + T_2\left(\frac{v_0 v^\Phi}{c^2} - \frac{{v^\Phi}^2}{2c^2}\right), \end{aligned} \tag{35}$$

where with the same accuracy $\tau_{AO} = T_1(1 - v_0^2/2c^2)$, $\tau_{OC} = T_2(1 - v_0^2/2c^2)$. It is obvious that $\tau_{AB} < \tau_{AO}$ for any $v_0, v_1^\Phi > 0$ (i.e. at the part AB the deceleration of the clock III in the FR II always takes place), and at the part BC both cases are possible — either $\tau_{BC} > \tau_{OC}$ (acceleration with respect to the clock II), or $\tau_{BC} < \tau_{OC}$ (deceleration) — according to the relation between v_0 and v_2^Φ. Deceleration is possible at BC too for the

*As far as the FR I and II are connected by the Galilee transformation, but not the Lorentz one, and have different metrics, we cannot reduce the case of an inclined (in the FR I) straight line to the case of the line cT by the simple transfer to the FR II, although in the FR II we will obtain cT' (AC on fig. 4). But because of the metric changing (existence of the non-diagonal part in (6)) the relation between the straight and broken line lengths is not already obvious.

physical velocity v_2^{Φ} great enough in the FR II, when the particle III velocity in the FR I is negative and more (by modulus) than v_0 (the point B at fig. 6 will be to the right of C).

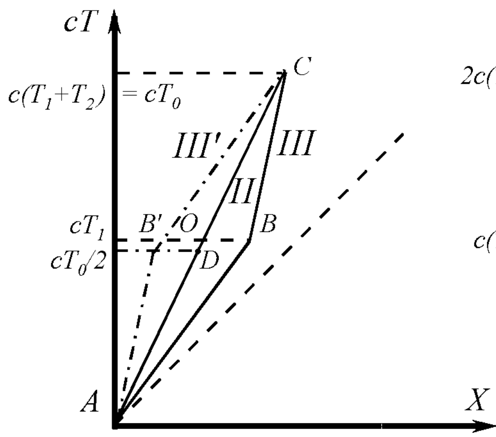

Fig. 4.

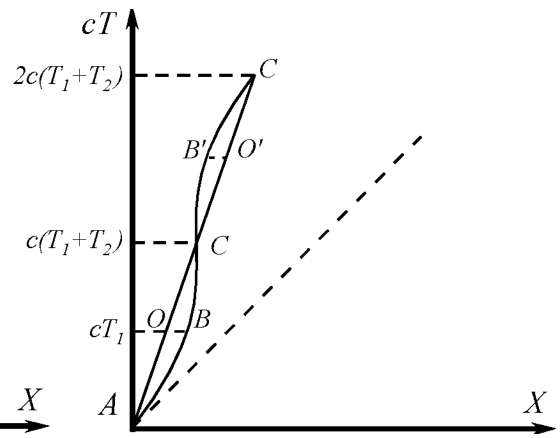

Fig. 5.

Let us note that the conditions $T_1 = T_2 = T_0/2$ and $v_1^{\Phi} = |v_2^{\Phi}|$ in the FR II are incompatible [3]: either $T_1 = T_2$, and then $v_1^{\Phi} \neq |v_2^{\Phi}|$, or $v_1^{\Phi} = |v_2^{\Phi}|$, and in this case $T_1 \neq T_2$.

Let us note that upon the accepted assumption of the particle III physical velocity equality in both directions in the FR II we have $\tau_{AB} = \tau_{BC}$, but $T_1 \neq T_2$ already for the first order with respect to v^2/c^2 and hence $\tau_{AO} \neq \tau_{OC}$. It is easy to verify that for the accepted accuracy $T_1 = \frac{T_0}{2}(1 + v_0 v^{\Phi}/c^2)$, $T_2 = \frac{T_0}{2}(1 - v_0 v^{\Phi}/c^2)$, $v_1 + v_2 = 2v_0(1 - v^{\Phi 2}/c^2)$, $\tau_{AO} = \frac{T_0}{2}(1 - v_0^2/2c^2 + v_0 v^{\Phi}/c^2)$; $\tau_{OC} = \frac{T_0}{2}(1 - v_0^2/2c^2 - v_0 v^{\Phi}/c^2)$ [3].

For the clock III total proper time along the whole trajectory ABC we have from (35) (in the second summand in (35) we can assume with the accepted accuracy $T_1 \cong T_2 \cong T_0/2$):

$$\tau_{ABC} = \tau_{AC} - T_0 \left(\frac{v^{\Phi^2}}{2c^2} \right), \tag{36}$$

where $\tau_{AC} = \tau_{AO} + \tau_{OC} = T_0(1 - v_0^2/2c^2)$.

Let us call attention to the appearance of summands proportional to the product $v_0 v^{\Phi}$ in (35). Thus, the clock III proper time at the parts AB and BC, expressed via their physical velocities in the FR II and the proper time of the FR II, explicitly depends on the velocity v_0 of the FR II in the inertial Galilee FR I even in the first order of v^2/c^2. In the expression for the whole proper time (36) this dependence on $v_0 v^{\Phi}$ vanishes (in the first order over v^2/c^2), however at the parts AB and BC it inevitably takes place (this corresponds to the deceleration or acceleration of the clock III in comparison with the clock II on the both parts and to their total deceleration at ABC — see par. 4 and theorem 1). Note that (see fig. 6) if one expresses for example τ_{AB} in (35) via $\tau_{AOC}/2 \equiv \tau_{1/2} \equiv \frac{T_0}{2}(1 - v_0^2/2c^2) \cong \tau_{AO} - (T_0/2)(v_0 v^{\Phi}/c^2)$, then $\tau_{AB} \cong \tau_{1/2} - (T_0/2)(v^{\Phi^2}/2c^2)$ and the dependence on $v_0 v^{\Phi}$ disappears. But the above calculation corresponds to the comparison of the clocks II and III readings not for the same moment of time T of the FR I, i. e. it doesn't to the clocks II and III proper time comparison at all. In fact, at the part AB we should compare the *tempos* of the clocks II and III, and this is possible at any point of this part [1] when the value $\tau_{1/2}$ is not defined. In other words we compare the values

$d\tau_{II} = dT\sqrt{1 - v_0^2/c^2}$ and $d\tau_{III} = dT\sqrt{1 - (v_0 + v^{\Phi})^2/c^2}$, i. e. $d\tau_{III} \cong d\tau_{II} - dT(\frac{v_0 v^{\Phi}}{c^2} + \frac{v^{\Phi 2}}{2c^2})$ (or the integrals $\int d\tau$ at any part of trajectories AB and AO, corresponding to the same time interval ΔT of the Galilee FR I).

Note, that the required comparison of the clocks II and III tempos at any point of the part AB is possible by the two methods [1, 3]. At first, it is possible to compare the clock III tempo with that of a number of "standard" clocks II "arranged" along the clock III trajectory (in the real laboratory conditions it may be an aggregation of identical atoms reposing in the FR II and emitting photons of the certain standard frequency) — the so-called "atom clock method". Secondly, the comparison of the clock II emitting periodic signals, distanced far from clock III with the clock III (far in comparison with the typical range of the clock III motion) along the axis Z from the hyperplane XT containing the clock III world line (the method of "pulsar" or that of "plane wave" [1, 3]). The intersection of the light cone of the clock II impulses with the hyperplane XT is (up to the arbitrary required accuracy) the straight line $T = \text{const}$ crossing any world line in the plane XT at the same moment T of the Galilee FR I. The presence of a photon at some point of the Minkowski 4-space is in turn the absolute fact independent of the FR choice.

Let us consider now a one-dimensional oscillator the null point of which (it is the FR II) moves uniformly along the oscillation direction with the velocity $v_0 \ll c$ in the inertial Galilee FR I (fig. 5). The particle III motion is assumed to be non-relativistic and its oscillations in the FR II are harmonic. We will calculate the clock III proper time in the inertial Galilee FR I. Since τ is the Minkowski space invariant, calculation in the generalized inertial FR II (of the oscillator null point) of non-inertial FR III (oscillating point) give always the same result (see par. 4). In this case for the particle III velocity in the FR I we can write the classic law of the velocity composition, i. e. $v(T) = v_0 + \Omega A \cos \Omega T$, where Ω is the frequency and A is the amplitude of the oscillations (for certainty we assume $\Omega A < v_0$). Thus at the parts of the relative (to the clock II) deceleration (AB) or acceleration (BC) of the clock III we have for the proper time differentials (clock tempo) the expressions analogous to (35):

$$\begin{aligned} d\tau_{AB} &= d\tau_0 - dT\left(\frac{v_0 \Omega A |\cos \Omega T|}{c^2} + \frac{\Omega^2 A^2 \cos^2 \Omega T}{2c^2}\right), \\ d\tau_{BC} &= d\tau_0 + dT\left(\frac{v_0 \Omega A |\cos \Omega T|}{c^2} - \frac{\Omega^2 A^2 \cos^2 \Omega T}{2c^2}\right), \end{aligned} \tag{37}$$

where $d\tau_0 = dT(1 - v_0^2/2c^2)$ is the proper time of the oscillator null point (the FR II).

Integrating (37) and summarizing both expressions, gives that the terms linear with respect to v_0 vanish, as in the previous example. So, for the whole proper time of the clock III at the part ABC (i. e. at the half-period) we have, as it was to expect, the deceleration only:

$$\tau_{ABC} = \tau_0 - \frac{\pi}{\Omega}\left(\frac{\Omega^2 A^2}{4c^2}\right); \qquad \tau_0 = \frac{\pi}{\Omega}\left(1 - \frac{v_0^2}{2c^2}\right). \tag{38}$$

Here τ_0 is the proper time interval of the oscillator (the FR III) null point, corresponding to the semiperiod of oscillation.

However, as well as in the previous example, at the parts AB and BC separately we have in (37) an unavoidable dependence on $v_0 v^{\Phi}$, describing the deceleration and acceleration of the clock III with respect to the FR II. To measure this variation of the clock tempo one can use one of the above methods.

Let us consider three methods of the experimental verifying of the expressions (37).

The first method was already offered in [1,3] — precise measurements of the pulsar impulse frequency. In this case ΩA in (37) equals 30 km/sec, and v_0 is the Sun velocity upon its rotation around the Galaxy center ($v_0 \simeq 200$ km/sec). So, we have the approximation $v_0/\Omega A \cong 7$; $\varepsilon_1 \simeq 5 \cdot 10^{-8}$, $\varepsilon_2 \simeq 2 \cdot 10^{-9}$. After all necessary corrections to the measurable pulsar frequency are brought in (the linear Doppler effect, secular deceleration of the pulsar etc.), one should expect a residual annual oscillation of the frequency with the amplitude of range $\frac{\delta\nu}{\nu} \simeq 5 \cdot 10^{-8}$ (the total deceleration of range $2 \cdot 10^{-9}$ seems to be out of the measurements accuracy).

The second (much more precise) method offered by us [3] can be executed using an artificial satellite of the Earth. For the experiment a so-called stationary satellite at the equatorial orbit (circulation time—24 hours exactly, altitude — $h = 34\,000$, circular velocity — ~ 3 km/sec) is required. For the amplitude of the frequency oscillations registered at the satellite we have the estimation $\delta\nu/\nu \sim v_0 \Omega A/c^2 \sim 5 \cdot 10^{-9}$ and their daily mean (total deceleration) is of $\overline{\delta\nu/\nu} \sim \Omega^2 A^2/2c^2 \sim 5 \cdot 10^{-11}$. These are quite measurable values (even during the data storage period of $\sim 10^2$ sec) in optical, as well as in SHF spectral band (the stability of the up-to-day quantum frequency standards is of 10^{-13}–10^{-14}).

The third method [3] — one more experiment with the satellite — the simplest one. In the experiment described above the difference of the emitter and receiver circular velocities is used (3 km/sec for the satellite and a much smaller one (which is neglected here for simplicity) $\sim$ 100–300 m/sec for a point on the Earth in dependence on the typical latitude). However this value at different latitudes on Earth' surface may be used for detecting of the effect $\sim v_0$. The only reliable method of communication of two distant clocks in this case — the usage of a stationary satellite being only a retranslator. For the difference of the emitter and detector circular velocities Δv^{Φ} of 100 m/sec (the latitude difference is of $\sim 40°$) we have the estimation of the daily frequency oscillation amplitude $\delta\nu/\nu \sim v_0 \Delta v^{\Phi}/c^2 \sim 2 \cdot 10^{-10}$, and their mean $\overline{\delta\nu/\nu} \sim \Delta(v_{\Phi}^2)/c^2 \sim 10^{-13}$ (if the detector is southward with respect to the emitter then $\overline{\delta\nu} > 0$, if northward — then $\overline{\delta\nu} < 0$).

Note, that in this variant of the experiment the total gravitational frequency shift of emitter photon upon its propagation to the satellite and back equals zero.

7. Conclusion. About the physical sense of the initial inertial Galilee FR

In the par. 2-4 on the basis of the covariant approach we have shown that the physical (proper) time does not depend on the coordinate choice — the choice of the time coordinate — at the non-inertial part of the mass motion, as well as at the inertial one of its uniform motion. This choice (different from that of the motion law specification) is really a matter of agreement. The choice $t = T$ [1] is singled by its simplicity — at the inertial part of motion we have the classic Galilee transformation for the connection with the initial inertial Galilee FR. The choice $t = \tau$ (where τ is the proper time, par. 2, 3) leads to the corresponding change of the connection between the time coordinates in the common Galilee transformation (providing the so-called "generalized Galilee transformation" — par. 3). But all this is only "a hand position" or "a clock-face partition" of the standard clock in the moving particle FR. The physical time tempo is of cause independent of it — in the moving particle FR it is always slower than in the initial Galilee FR (the absoluteness of the time deceleration effect).

It is important to emphasize that the noted arbitrariness of the time coordinate determination changes only a concrete metric expression at the inertial part of the particle motion, but not its class. The metric remains always in the generalized inertial (non-diagonal) metric class, and in no way coincides with the initial Galilee one. Therefore the metric is connected with it by the generalized Galilee transformation, but not the Lorentz one. The generalized Lorentz-Poincare group transformations (either inertial or noninertial ones — see [1] and par. 2) are those of the *symmetry* group of all physical laws, i. e. those of the metric forminvariance group in the correspondent physical FR. But these transformations *cannot be* connected with any real mass motion, they are only those of abstract 4-motions (changing of the point arithmetization) in the Minkowski space. The symmetry group transformations and the FR transformations of real moving masses are completely different concepts*.

The proper time in the generalized inertial FR of material bodies runs always *slower* than in the Galilee FR. And if we compare the proper time tempos in these FR's, we will find the difference [1]. In the par. 6 we estimated several methods of the experimental verification of the dependence of the proper time on the laboratory absolute velocity in the inertial Galilee FR. All they are based on the comparison of some standard source *frequency* in the FR II (laboratory) and the moving particle FR. Let us emphasize the principle distinction of this situation from the unsuccessful attempts to find an absolute laboratory velocity with respect to the light-bringing "ether" [8, 16]. All numerous attempts to find the ether (modified experiments of Maikelson, Kennedy-Torndike etc.) were executed under the assumption that in the only FR where the ether reposes the light *velocity* equals c and motion with respect to the ether *changes* this velocity. From the viewpoint of the covariant approach to the SRT all these experiments should give (and give!) the negative answer. In fact, in all generalized inertial FR's the *physical velocity* of light (par. 4) (i. e. the very velocity which is observed or measured) is isotropic and equals c globally [1–3]. The same is valid in any non-inertial FR (but for the local measurements). *Only* comparing the proper time, i. e. the standard (atom) process *frequencies* (but not the effects connected with the light velocity!) we can differ the generalized Galilee FR from the Galilee one and so determine the laboratory absolute velocity in the Galilee FR. Thus, all classical experiments do not violate the above ideas. By our opinion, the satellite experiment (par. 6), in which the two atom clocks (moving with different velocities) frequencies are compared, could be the last test of the ideas. In this experiment the

*A simple and intuitively understandable example: an abstract turn of a three dimensional coordinate system (symmetry transformation) with the fixed origin is not identical to a real mass turn (which is inevitably followed by the appearance of forces, accelerations etc.) the same concerns the generalized Lorentz turn, involving the time axis. However the existence of the symmetry group in any FR has an important significance — it leads to the existence of the conservation laws and to the known relativistic relations for the physically measurable values. Ten parameters of the symmetry group — the generalized Poincare one — correspond to 10 motion integrals [1, 2].

straightforward chack of the clock proper time dependence on its absolute velocity in the inertial Galilee FR is possible.

The existence of the initial (singled) inertial Galilee FR with the metric (1) has, to our opinion the clear physical sense. All the inertial FR's dealt with are obviously, such only up to some accuracy degree: the Earth rotates around its axis and the Sun, the Sun does around the Galaxy center, the relative motion of the Galaxies is possible also. But if we connect a FR with the galactic background, i. e. with the Universe at whole, this will be the initial inertial Galilee FR. It is clear that to say about the uniform motion of the Universe is senseless — it is given to us in one exemplar. Thus the *origin* in this FR is fixed (it has never accelerated), but the FR is not unique — it is determined up to the abstract transformations of the Lorentz-Poincare symmetry group (i.e. up to the three-dimensional rotations, shifts and Lorentz rotations).

The coordinate time T in this initial Galilee FR is the real (physical) time which can be called *"the world"* one. The proper time of any mass moving arbitrarily in the initial FR is always slower than the world one — it is a fundamental property of the space-time. And we can therefore determine the body absolute velocity in this single FR, and so determine the world time tempo. Is the concept accounted the return to an absolute space concept? No, to say correctly, it is a concept of an absolute space-time. There is no relativity of the uniform motions, as well as relativistic effects. All essence of the SRT is in postulating of the pseudo-Euclidean space-time existence, the existence of the initial inertial Galilee FR with the metrics (1).

In the conclusion the author makes an acknowledgements to A. A. Logunov, Yu. V. Baryshev and G. M. Telezhko for the discussion of a number of problems touched here and some useful notes.

References

[1] *Genk A. V.* // Gravitation. **V. 3**, iss. 1 (*1997*), pp. 55–75.

[2] *Logunov A.A.* "Lectures on the relativity and gravity theory (recent analysis of the problem)". M: Nauka, *1987* (in Russian).

[3] *Genk A.V.* "The Theory of relativity (introduction in recent analysis)". // Gravitation. **V. 3**, iss. 2 *1997*, pp. 26–50.

[4] *Fock V.A.* "The Theory of Space, Time and Gravitation". Pergamon Press, *1955*.

[5] *Misner C., Thorn K., Wheeler J.* "Gravitation", Freeman W.H., San Francisco, *1973*.

[6] *Anisovich K.V.* "Logical aspects, principles and methodology of the special relativity theory". Deposited manuscript, VINITI N 8156-B87. M: VINITI, *1987* (All Russian Institute of technical information) (in Russian).

[7] *Zelmanov A.L., Agakov V.G.* "Elements of the general relativity theory". M: Nauka, *1989* (in Russian).

[8] *Møller C.* "The Theory of Relativity". Clarendon Press, Oxford, *1972*.

[9] *Telezhko G. M.* //Gravitation. **V. 3**, iss. 1 (*1997*), pp. 76–82.

[10] Mösbauer's effect (collection of reports). M.: Foreign literature *1962*. Atomizdat *1969* (in Russian).

[11] *Hay H., Schifer J., Cranshaw T., Egelstaff P.* //Phys. Rev. Lett., V. 4 (*1960*), p. 165; *Kundig W.* // Phys. Rev., V. 129 (*1963*), p. 2371.

[12] *Logunov A.A., Chugreev Yu.V.* // "Uspekhi Fizicheskikh Nauk" ("UFN"). **v. 156**, iss. 1 (*1988*), pp. 137–143 (in Russian). English edition: "Physics-Uspekhi".

[13] *Einstein A.* Ann. Phys. *1905*, **17** P. 891-921.

[14] *Gold T.* The nature of pulsars, in: Contemporary Physics.— Trieste Symposium *1968* **vol. 1**. *Hewish A.* Pulsars, in: Annual Review of Astronimy and Astrophysics M. *1970*.

[15] Time and frequency (ed. D. Jespersen). M., *1973*. *Lekhotov V.S.* // "UFN", **v. 48** *1978*, iss. 2, p. 199. (in Russian).

[16] *Møller C.* // Proc. Roy. Soc. *1962*. **V. A270**, p. 306; *Strahovsky G.M., Uspensky A.V.* // "UFN". **v. 86** (*1965*), P. 421 (in Russian).