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EXPERIMENT AND CONCEPTS OF THE RELATIVE KINEMATICS

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In the Newton's mechanics the absolute time interval (absolute distance) is ascribed to the two events (points) even if no apparatuses exist one could measure them with. Even more, different space coordinates (e.g., different axes) may correspond to the absolute distance. But the absolute time interval itself is the only time coordinate.

In the Special Theory of Relativity (STR) a variety of time intervals related to different systems of reference (s.r.) correspond to the two events. But as it was before and is in STR now the time interval itself in the given s.r. is the only time coordinate. In recent time much attention is given to the discussion of the statement: even in one and the same s.r. one may choose a variety of time coordinates under different conventions of simultaneity [1]. From my point of view [2] this activity shows that the STR concepts (time, simultaneity, distance) and statements (isotropy of light velocity, relative clock retardation and rod contraction) imply nontrivial conventions. In this connection the pioneer works [3] by Poincare, Reichenbach, Robb became newly actual.

1. But though one may use any agreed coordinate, they all should be expressed through inconventional quantities measured in the experiment. Within the operational approach to kinematics (OAK) [2] the readings of clock set are taken as these quantities. In this paper let us compare the concepts and statements of STR and OAK in connection with some experiments. The definitions and concepts of OAK are introduced according to the operational principle, i.e., considering the experimental procedure with which the corresponding values can be measured.

The "absolute" time interval $\tau_{12}(0)$ is defined as the difference of the clock readings between the events 1 and 2 taking place at clock site only (point 0). The time interval refers to a given clock but not to a system of reference.

If events a and b occur at different sites, then the experimental connection between them and a given clock can be established only with the help of signals (e.g., electromagnetic γ-signals). This connection is characterized by two events of γ-signal departures from the clock of point 0 towards the points of events a and b and two events of γ-signal arrivals at clock site being reflected from points in which events a and b occur. Let us introduce the denotions: $\tau^-_{ab}(0)$ is the time interval by the clock at 0 between the departures and $\tau^+_{ab}(0)$ – between the arrivals of γ-signals at 0. We shall also use these denotions and in the case, if only one event occured at a clock point. In OAK only a variety of standard clocks and γ-signals are used as the measuring apparatuses. And with the help of τ^-, τ^+ all the kinematical experiments were described [2]. In STR on accepting the convention of constant one-way light velocity it is also possible to express the length standard through the time standard.

2. We consider the relative motion of two points A and 0, if the poin A moves through (event 1) and away from point 0, and some ev.2 occurs in point A near to ev.1. There by the clocks at 0 only $d\tau^-_{12}(0)$, $d\tau^+_{12}(0)$ may be measured. Let us call $d\ell_{12}(0) = (d\tau^+_{12} - d\tau^-_{12})/2$ the location coordinate of ev.2 (in point A) with respect to point 0 and $V_A(0) = (d\tau^+_{12} - d\tau^-_{12})/(d\tau^+_{12} + d\tau^-_{12})$ the velocity of point A with respect to point 0. The quantity $V_A(0)$ characterizes not only the motion of the object with respect to p. 0, but also that of γ-signal. Important that the trajectory is went by the object as well as by γ-signal. Therefore the so-called "one-way velocity" (the one-way trajectory is went either by the object or by γ-signal) cannot be measured. The value $V_A(0)$ is numerically equal to the value v/c in STR. But in OAK the velocity is not interpreted as a distance went in a time unit. As a consequence of the above given definitions we obtain the following identities:

$$d\ell(0) \equiv \frac{v}{1+v}\, d\tau^+ \equiv \frac{v}{1-v}\, d\tau^- \equiv v\, \frac{d\tau^+ + d\tau^-}{2}. \qquad (1)$$

3. In AOK points A and B let us define to be at rest with respect to each other, if the intervals between the departures of two γ-signals from one point ($\tau_{12}(A)$ or $\tau_{34}(B)$) is equal to that between the arrivals of these signals to the other point ($\tau^+_{12}(B)$ or $\tau^+_{34}(A)$), i.e., for the points at rest one may speak about the absence of the Doppler effect. As a result, for such points the location coordinates of different events in one point relative to the other do not change with time. In OAK we use the term "distance" only for this location coordinate between the points at rest. So, the distance corresponds to a pair of points at rest. This fact allows one to operate with the three-dimensional space of points at rest. The difference between the concept of the distance and that of the location coordinate is under discussion in item 8.

If in the system of points at rest the times of γ-signal flight along any closed trajectory in both directions are equal, then the points of this system used for measurements (and clocks placed in them) will be called the s.r. Let me note that for the points rotating uniformly along the circumstance the above is not true and thus though being at rest relative to each other they cannot be used as a system of reference (see i.5). Here we do not speak about the inertial s.r., since in OAK differently from STR the s.r. is defined in the beginning of the kinematics construction with the kinematical methods only. While in STR the s.r. is practically defined in the following way: only such system is inertial where the STR laws hold.

4. After the definitions are introduced the following is postulated:

1) The motion of the source of γ-signal does not affect the propagation of the γ-signal. Therefore, it is convenient for the measurements to use γ as a signal;

2) The two clocks arbitrary moving away from some point have "equal rights" in the observation of the Doppler effect (on γ-signal exchange) in a short enough time after coincidence. In other words this requirement means that $V_A(0) = V_0(A)$. We insist on satisfying the "equal rights" requirement either clocks move uniformly or with acceleration relative to other points. The latter allows to describe the behaviour of accelerated clocks (differently from STR). In general the "equal rights" requirement might not hold for a certain clock in accelerated motion with respect to s.r. (after all, a very strong acceleration destroys the clocks).

5. As a consequence of the "equal rights" postulate we get the relationship between the readings of two clocks A and 0 moving through some point.

$$d\tau_{12}(A) = d\tau^+_{12}(0)\sqrt{\frac{1-v}{1+v}} = d\tau^-_{12}(0)\sqrt{\frac{1+v}{1-v}}, \quad d\ell_{12}(0) = \frac{v}{\sqrt{1-v^2}}\, d\tau_{12}(A). \qquad (2)$$

Important that equations "equal in rights" with (2) may be also written, but only for the events belonging to another signal exchange $d\tau_{13}(0) = d\tau^+_{13}(A)[1-v]^{1/2}[1+v]^{-1/2}$ and so on. Knowing the trajectory of point A in any s.r. and its velocity V_A with respect to the points of trajectory one may fully characterize the motion of point A. But the motion of p. A may be measured by the lonely clock belonging to some trajectory point 0. For this purpose one should measure the functional relationship between $\tau^+(0)$, $\tau^-(0)$ for γ-signals sent to p. A and those came back to p. 0 along the trajectory of

p. A. In this case equations (1) and (2) hold (then the events 1 and 2 correspond to the reflections of neighbouring γ-signals from point A).

In this case, generally speaking, the remoted clocks A and 0 do not keep the equality of rights, because the trajectory is given in s.r., of p. 0, but not of p. A. Only, if p. A moves uniformly and rectilinearly in the s.r. of p. 0 and belongs to another s.r., there may exist an "equal rights" exchange of γ-signals between the points A and 0 [2].

Using (1) and (2) for the closed trajectory of clock A we obtain:

$$\tau(0) = \int_0^{\tau(A)} [1-v^2]^{-1/2} d\tau(A), \quad \tau(0) > \tau(A). \tag{3}$$

Here the readings of clocks are taken between the two coincidences of clocks A and 0. Only such comparison of clock readings (e.g., meson decay in the storing ring) is interpreted in OAK as the clock retardation. There is no need in signals for such a comparison, but one needs them to get eq.(3). From here it follows that all the signals satisfying the postulated in item 4 must have V=1. Alternatively, operating in mind with different signals we would get different V_A, that is different clock retardation.

It is also easy to describe the Sagnac's type experiments. Let the clock A move from point 0 (ev. 1) along a part of closed trajectory. In opposite directions but also along this trajectory the γ_{13} and γ_{14} singsignals are sent from point 0 (ev. 1). Events 3 and 4 are their arrivals at the point of clock A, respectively. Then on the basis of eqs. (1) and (2) we have

$$\tau_{13}(A) = \int_0^{\tau_{13}^{+}} \sqrt{\frac{1-v}{1+v}}\, d\tau^{+}(0), \quad \tau_{14}(A) = \int_0^{\tau_{14}^{-}} \sqrt{\frac{1+v}{1-v}}\, d\tau^{-}(0).$$

Since the time of γ-flight along the trajectory is independent of the direction of flight and is equal to the length of the trajectory (see i.3), then $\ell = \tau_{13}^{+}(0) = \tau_{14}^{-}(0)$. Having the above states in mind we get for V=const the simple equation

$$\tau_{14}(A) - \tau_{13}(A) = 2\ell \frac{v}{\sqrt{1-v^2}}. \tag{4}$$

As is seen from eq. (4) the Sagnac's experiment does not allow one to measure V_A of point A without using some s.r. Strictly speaking, its non zero result for the Earth shows only that γ-trajectory is not bound with the points of s.r. (see i.3).

6. A system of reference allows one to describe the general case of γ-signal exchange between remoted clocks, if one knows the motion of the source $(V_A(0))$ and of the detector $(V_B(0))$ in some s.r. noted with point 0:

$$\int_0^{\tau_{12}} [1-V_A^2(0)]^{-1/2} d\tau(A) + r_{24}(0) = \int_0^{\tau_{34}} [1-V_B^2(0)]^{-1/2} d\tau(B) + r_{13}(0), \tag{5}$$

where events 1 and 2 are the γ_{13}, γ_{24}-signal departures from p. A and events 3 and 4 are those signals arrivals at point B, respectively, r_{ab} is the distance between the points of s.r. in which events a and b take place. Here the trajectories of points and γ-signals together compose the closed trajectory as in the equation given earlier. That, generally speaking, trivial fact explains why the concept of time in OAK (see i.1) allows to describe the kinematical experiments.

Important is that all the above results do not require the knowledge of the geometry of space of points at rest. If one assumes the Euclide geometry, then the distances in (5) are more conveniently expressed through angles. Then the relationship for the Doppler effect is obtained from (5) when r_{12} and r_{34} tend to zero:

$$\tau(A) \frac{1-V_A(0)\cos\alpha(0)}{\sqrt{1-V_A^2(0)}} = \tau^{+}(B) \frac{1-V_B(0)\cos\beta(0)}{\sqrt{1-V_B^2(0)}}. \tag{6}$$

Here angles α and β taken from trajectories of signals to those of p. A and p. B, respectively, values of V_A, α are taken between the events of γ-signal departures and V_B, β - between γ-signal arrivals. If a set of clocks moves uniformly along circumstances with the mutual centre (R_A, R_B) then:

$$d\tau(A)\left[1-\ell\frac{V_A}{R_A}\right]\sqrt{1-V_B^2} = d\tau^{+}(B)\left[1-\ell\frac{V_B}{R_B}\right]\sqrt{1-V_A^2}, \tag{7}$$

where ℓ is the distance from the centre to trajectories of γ-signals. If $V_A=V_B$ and $R_A=R_B$, then points A and B are at rest, but a set of such points cannot serve as a s.r. (see i.3 and eq. (4)).

7. The interpretation of many experiments becomes simplier, if the observation of the Doppler effect (eq. (6) at $V_A(0)=0$) is considered as the measurement of velocity $(V_B(0))$ of point B with respect to a distinct point 0 belonging to the s.r. The vector V_B is determined with the help of three such measurements with respect to some three points of s.r. But this

will be possible after investigating with the help of a set of points at rest belonging to some s.r. of the geometry of the part of the world where p. B and γ-signals are moving. In the alternative case (e.g., in cosmology) equation (6) may be used only as a hypothesis.

Thus the kinematical experiment must be started with the experimental proof of the existence of s.r. But in practice a rigid body is used as a s.r. But one should show in the experiment whether this assumption is possible. Besides, rigid bodies are used as a construction material for apparatuses. As a consequence, real experiments examine both the kinematical equations and the assumed properties of the rigid body.

The OAK avoids accepting the kinematical properties of rigid bodies as conventions (e.g., convention about self-congruence of the length standard on its transference). Therefore in OAK the kinematical properties of the rigid body can be and must be tested by means of the kinematical experiment. So, it seems reasonable to aks whether the length of the rigid rod depends on its position in s.r. (e.g., its orientation, or on its transference in another s.r.). But one cannot predict an answer within the kinematics.

For example, the Michelson's type experiment establishes the constant ratio of the basis distance went by light to its wave-length on variation of the basis orientation in space.

The Sagnac's type experiment (i.5) can be considered as a comparison of the average rotor velocity measured over the number of rotations with the velocity of a semitransparant mirror along a short section of the circumstance calculated by using the γ-signal exchange described by eq. (4) (in the real Sagnac experiment the latter velocity is also averaged).

Similarly, on the observation of the Moessbauer effect the rotor experiment establishes the equality of the average and instantaneous velocity of the rotor. In ref. [4] it was proved that this is true both for the instantaneous velocity directed in the orbital motion of the Earth and for the case of its opposite direction. This is in agreement both with kinematics predictions and with assumed rotor properties. It is not customary to us that the space properties of the body would be anisotropic (e.g., within the Mach principle) but then the average velocity could not be equal to instantaneous one. We see that the properties of the rigid body affect the real kinematical experiments. But in principle predictions of OAK can be prooved separately from the dynamics.

8. In the above relationships one compared the time intervals of any two clocks (the events occur at clock site). But

the events 1 and 2 remoted from clocks may be coordinated with the help of lonely clocks belonging to any s.r. and γ-signals [2]. In ref. [2] it is shown that two quantities $\mathbf{r}_{12}$ and $T(\eta)=\bar{\eta}\cdot\bar{\mathbf{r}}_{12}+(r^{+}_{12}+r^{-}_{12})/2$ ($\bar{\eta}$ – any unit vector) corresponding to events 1 and 2 are invariants in the s.r., i.e., they are independent of the choice of the measuring clock belonging to this s.r. Therefore a pair of events is characterized by the four coordinates of any coordinate system in a given s.r. These four independent coordinates are expressed through the three pairs of r^{+}, r^{-} type quantities connected by two equations and measured with three clocks not lying in one and the same straight line.

The STR uses projections of $\mathbf{r}_{12}$ on orthogonal space axes as space coordinates and a particular case of the second invariant $[r^{+}_{12}(1)+r^{-}_{12}(1)]/2$ as the time coordinate. And the concepts of time and time coordinate being not distinguished. But quantities, for example, $T(\eta)$ may with equal success be used as the time coordinate [2]. This is one more reason for distinguishing the time interval from time coordinate in OAK. In STR the difference between the location coordinates for a pair of events taking place at the ends of the rod is called the length of the rod in any s.r., if for these events $T(\eta=0)=0$. But as a consequence of the simultaneity convention such concept of the rod length is not introduced in AOK. Here the length is the distance between the end points at rest of the rod and characterized only the rod irrespective to any s.r. The OAK distinguishes the time and time coordinate, the distance and location coordinate in order to exclude the conventional statements of STR. Therefore, the OAK has no need in concepts of relativity of time and distance. Of course the signal coordinates r^{+}, r^{-} are relative in that trivial sense that they are measured by clocks belonging to s.r. But the time coordinates $T(\eta)$ are relative both with respect to the s.r. and to the convention of choice of the type of the time coordinate (e.g., a choice of η).

Let us note one more difference between the STR and OAK. The STR is actually base on Lorentz transformations (the STR postulates are only the scaffoldings for them). All the experimental predictions of the STR must be the consequences of them. Therefore, clock readings can be compared only for the clocks belonging to different s.r. This is why one cannot make an attempt to describe the behaviour of accelerated clocks within STR. For them the principle of relativity is not true. The consideration of the rotor experiments within STR is simply the fitting to the known experiment. And it is not clear why the result of this consideration is in agreement with the experiment.

But the OAK allows to understand this fact. In principle for OAK it is quite enough to have one s.r. And the principle of relativity, understood as a requirement of the "equality of rights" for a variety of s.r.,can either exist or not independently of postulates and consequences of OAK. And the Lorentz transformations are obtained for the particular case of the measurement of signal coordinates (r^+, r^-) with the help of two clocks belonging to the two really existing s.r. (One should remember that the real s.r. is limited in time-space). But here the s.r. themselves can differ very much. One of them allows the measurement of the geometry in the part of the world we make the experiment. The other may be represented by just three clocks moving uniformly and rectilinearly with respect to the first s.r. (the clock being not on one and the same straight line). For a particular choice of a pair of events (e.g., events taking place at the site of the clock moving rectilinearly and uniformly) it appears enough to take a lonely clock in other s.r.

"Some correspondings" are seen between the principle of relativity and postulate of "equal rights" of clocks (i.4). The principle of relativity may be interpreted with the existence of several laboratories so "screened" from the surrounding universe that the latter "does not affect" the experiments inside the laboratories. Actually the "equal rights" of clocks is a particular case of the principle of relativity in a restricted range (locality) of time-space. But the principle of relativity is not a very good postulate, since it sets requirements on any experiment, it is more useful as a powerful method for the initial building up of the theory. The "equality of rights" postulate seems more convenient for describing the kinematics on axiomatic basis, since there are postulated the requirements for the elementary kinematical experiment, and these requirements are local.

Thus describing all the known kinematical experiments, the OAK does not need the concepts of relativity of time-space (clock readings and length are "absolute") and the requirement for "equal rights" of various s.r. (principle of relativity).

In conclusion let us note that possibly it is not difficult to change the "equal rights" postulate for clocks, by introducing the prefered s.r. or any prefered direction. Our universe is anisotropic, therefore one may expect its anisotropic effects on laboratory experiments. Modern achievements in experimental accuracy allow to perform such experiments or derive estimates from experiments made on other purposes.

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