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PROPAGATION OF SIGNALS IN SPACE WITH MULTI-DIMENSIONAL TIME

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Introduction

The theory in which time is considered equally with space co-ordinate $\mathbf{x}$ as a three-dimensional vector $\hat{t}$ [1] is a next step in a symmetrization of space-time properties which has been begun by Poincare-Einstein theory of relativity and was continued in Dirac, Fock, Tomonaga and other author's investigations (see paper [1] where more detailed bibliography is cited). Several physicists developed this theory hoping to avoid in that way the earnest difficulties with Lorentz transformations peculiar to tachyon models and, generally speaking, to any non-local theory [2 - 4].

The position of a body in six-dimensional world is determined by co- and contravariant vectors

$$(\hat{\mathbf{x}})_\mu = (-\mathbf{x}, c\hat{t})^\mu \quad , \quad (\hat{\mathbf{x}})^\mu = (\mathbf{x}, c\hat{t})^{T\mu}.$$

The location of the body on its time trajectory can be characterized by a scalar "proper time" t. However, if vector $\hat{t}$ is defined quite uniquely, the quantity t can be determined in two different ways: as a length of the trajectory from a point M_o

$$t = \int_{M_o}^{M} |\hat{t}| = \int_{M_o}^{M} \sqrt{dt_1^2 + dt_2^2 + dt_3^2} =$$

$$\int_{\xi}^{\xi} \left[\sum_{i=1}^{3} (dt_i(\xi)/d\xi)^2 \right]^{1/2} d\xi,$$

where ξ is a parameter (see Fig.1), or as the difference of the distances from a co-ordinate origin

$$t_d = \left| \int_{M_o}^{M} d\hat{t} \right| = \left| \hat{t}(M) - \hat{t}(M_o) \right|.$$

[1] Here and in what follows vectors in x- and t-subspaces are denoted, respectively, by bold face and by a "hat". Six-dimensional vectors will be denoted at once by bold face and the "hat". In manuscripts it is convenient to use the notations $\bar{x}$, $\hat{x}$ and $\hat{\bar{x}}$. We shall also suppose that the latin and greek indices take values $k = 1, ..., 3, \mu = 1, ..., 6$).

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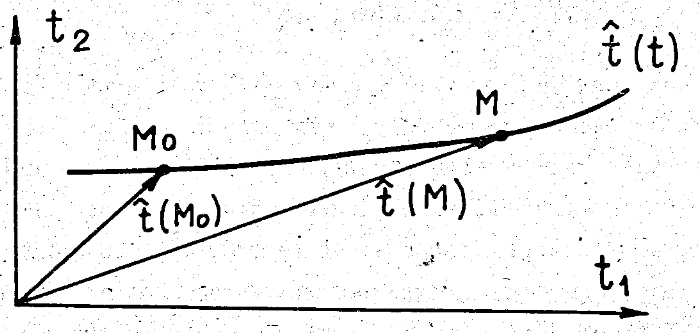

Figure 1: Two ways to determine the proper time interval between events M_o and M: along the trajectory or as the difference of the event distances from a co-ordinate origin.

Obviously, $t_d \leq t$ and

$$dt_d \equiv d|\hat{t}| = t_i dt_i/|\hat{t}| = \hat{t} d\hat{t} = |\hat{t}| \cos\varphi,$$

where φ is the angle between the vectors $\hat{t}$ and $d\hat{t}$.

In what follows we shall use $dt = |d\hat{t}|$, i. e. measure the proper time increment along the trajectory $\hat{t}$. As a parameter ξ, we choose the time t itself, then the trajectory $\hat{t}(t)$ is determined by the unit vector $\hat{\tau}(t) = d\hat{t}/dt$. When body movement is radial in t-subspace $\hat{\tau} = \hat{t}/t = const.$

Directions of time

Basing on the above mentioned definition of time multi-dimensionality, we shall suppose that our theory answers two cardinal requirements: Lorentz invariance and time irreversibility. So as the first one was minutely discussed in papers [4 - 7], let us confine oneself by a consideration of time directions.

The irreversibility of time, i. e. the impossibility to reproduce any event in all its details backward in time is a direct consequence of an

inexhaustibility of inner and outer interconnections of every material object. Namely this property of Nature but not anyone specific time non-invariant process is a cause of the invariant "time arrow". As a rule, an amount of final states in destructive processes is always greater than a number of states creating by a regularity, therefore, an evolution of the system (its time arrow) directs to an increasing of chaos. A punctual repetition of all alterations of the system is possible only in an approximate theories taking into account a finite number of parameters. Only such theories are T-invariant what, however, comes never true in the real world where one can find in every process a preceding cause and its more late in time effect. On philosophical level it is formulated as the principle of causation (of retarded causation, more precisely [8]).

Several elucidation of time irreversibility must been added in the case of elementary particle interactions which possesses a high symmetry with respect to a change of time direction. Some authors (see, for example, the books [9.10]) conclude on these grounds that the time irreversibility is purely macroscopic property arising in a process of averaging of T-invariant microscopic events. One must not forget, however, that our description of elementary processes demands to take into account macroscopic surroundings. This circumstance is reflected yet in a notion of ψ-function itself. When, describing elementary processes, we attract oneself away from a consideration of accompanying time irreversible alterations of the macroscopic, large scale surroundings, it means only a some idealization, an approximate excising of important for us phenomena from an extremely complicated background of unessential details. One can say that T-invariance is peculiar to physical laws but not to reality itself.

Basing on the mentioned material cause of the time irreversibility, one has to admit that this property must be true for any time direction, i. e. projections of all time trajectories on the axes t_i must be always positive:

$$\hat{\tau} = d\hat{t}/dt \geq 0. \tag{1}$$

Particularly, in the two-dimensional case the t-trajectory of every body must pass on from the third angular quadrant to the first one. So, the observer moving along some trajectory $\hat{t}$ can describe events by means of the measured along this trajectory one-dimensional "proper time" t since the last one can be used as a parameter defining the vector function $\hat{t}(t)$.

From the cosmological point of view such conditions are equivalent to a supposition an existence of some preferred ("relict") reference frame ("the time arrow" in one-time case) fixed by an event order which was set up at first moments after creation of our universe [11]. The use of other co-ordinate systems turned with respect to the relict one makes sense of a formal renumbering of time co-ordinates just as an inverse time reading which we use some time in our everyday practice. It is important, however, to note that the proper time measured along the t-trajectory in the direction of the body motion remains always positive.

As an inflation swelling of the universe violated a space-time co-ordination of its remote regions (during the superluminal inflation there is no point in a notion of the co-ordinate system), these regions can possess the own relict reference frames and exist in a times which are different from ours. However, due to a great space between such parts of the world, a chance to meet any body with "not our" time trajectory is as small as a chance to discover a relict magnetic pole (if only such bodies are not created anywhere inside our part of the universe).

Velocity in six-dimensional space-time

Like the usual one-time theory where every space vector **x** determining a body position is a function of the time variable t, let us consider each vector **x** of the six-dimensional theory as a function of a three-dimensional variable $\hat{t}$. At this point we see that time (a characteristic of any alteration) is, as before, singled out in comparison with the space co-ordinates and the complete space-time symmetry fails.

Defining the velocity, one must take into account that a body t-trajectory is also time-dependent, and therefore, instead of three-dimensional velocity **v** we must consider a 6×3 matrix with elements

$$V_{\mu k} = (dx_k/dt_i, cdt_k/dt_i)^T = (v_k, c\tau_k)^T/\tau_i = \hat{\mathbf{V}}_k/\tau_i, \quad (2)$$

where $\hat{\mathbf{V}}$ is the six-dimensional derivative with respect to the body proper time t. This derivative is exactly equal to the velocity along t-trajectory $\hat{\tau}$:

$$\frac{d\hat{\mathbf{x}}}{d\hat{\tau}} = -(\hat{\tau}\hat{\nabla})\hat{\mathbf{x}} = \tau_i\frac{\partial\hat{\mathbf{x}}}{\partial t_i} = \hat{\mathbf{V}}, \quad (3)$$

where $\hat{\nabla} = (-\partial/\partial t_1, -\partial/\partial t_2, -\partial/\partial t_3)$ is the time analog of three-dimensional space operator ∇ taken with the opposite sign.

The relation (3) is a particular case of the more general expressions for a total time derivatives determined by a change at the considered point $\hat{\nabla}A(\hat{\mathbf{x}})$ and a change due to a displacement to another point along the trajectory $\hat{t}(t)$:

$$\hat{\tau}\frac{dA(\hat{\mathbf{x}})}{d\hat{t}} = \frac{dA(\hat{\mathbf{x}})}{dt}, \quad (4)$$

$$\frac{dA(\hat{\mathbf{x}})}{dt} = \{\lim_{\Delta t \to 0}[A(\hat{\mathbf{x}} + \hat{\mathbf{v}}\Delta t) - A(\hat{\mathbf{x}})]/\Delta t\} = dA/d\mathbf{v} + dA/d\hat{\tau} = -(\hat{\mathbf{v}}\tilde{\nabla})A, \quad (5)$$

where six-dimensional operator $\tilde{\nabla} = (\nabla, -\hat{\nabla}/c)$, the scalar product $\hat{\mathbf{v}}\tilde{\nabla} = \hat{v}\hat{\nabla} - \mathbf{v}\nabla$ and the obvious equality $d\hat{t} = \hat{\tau}dt$ is taken into account.

At the some time one has to bear in mind that the quantities v_{ij} defined by the relation (2) could be named velocities only very relative since at a fixed value of i they do not possess properties of a vector. For instance, it is seen from (2) that

$$v_i^2 = (\sum_j v_{ij}\tau_j)^2 \neq \sum_j v_{ij}^2 \quad (6).$$

Only the summary quantities v_i are components of a vector $(v^2 = \sum_i v_i^2)$.

If we notice now that a differential of the squared length in the six-dimensional space-time

$$ds^2 = c^2(d\hat{t})^2 - (d\mathbf{x})^2 = c^2(dt)^2\,[1 - \frac{1}{c^2}(\frac{d\mathbf{x}}{dt})^2] = dt^2/\gamma^2, \tag{7}$$

where $\gamma = [1-(v/c)^2]^{1/2}$, then the velocity vector can be written in the covariant form

$$\hat{\mathbf{u}} = d\hat{\mathbf{x}}/ds = \gamma d\hat{\mathbf{x}}/dt = \gamma\hat{\mathbf{v}}. \tag{8}$$

As in the one-time case the scalar product

$$\hat{\mathbf{u}}^2 = \gamma^2\hat{\mathbf{v}}^2 = \gamma^2(c^2\hat{\tau}^2 - \mathbf{v}^2) \tag{9}$$

and a light wave front has always the spherical form:

$$\sum_i(\Delta x_i^2 - c^2\Delta t_i^2) = \Delta t^2\sum_i(v_i^2 - c^2\tau^2) = \Delta t^2(v^2 - c^2) = 0. \tag{10}$$

In any direction of t-subspace the body speed does not exceed the light velocity: $|v_{ij}| = |v_i\tau_i| \le c$.

If a matrix v_{ij} is known, it is not difficult to calculate the position vector of the body moving along a trajectory $\hat{\tau}(t)$:

$$x_i(t) = \int_{\tau(t)} \frac{dx_i}{d\hat{t}}d\hat{t} = \int_{\tau(t)} v_{ij}dt_i =$$

$$\int_{t_0}^{t} v_{ij}\tau_j(t)dt = \int_{t_0}^{t} v_i(t)dt. \tag{11}$$

The body space displacement (the length of its space trajectory)

$$S(t_0,t) = \int_{t_0}^{t}\{\sum_{J=1}^{3}[v_{ij}(t)\tau_j(t)]^2\}^{1/2} = \int_{t_0}^{t} v(t)dt. \tag{12}$$

It is very important to emphasize that the body speed v is defined with respect to an increment Δt along the time trajectory $\hat{t}$. If it is unknown and an observer takes advantage of his proper time $\Delta t_d = \Delta t \cos\theta$, then the quantity $\mathbf{v} \equiv \Delta\mathbf{x}/\Delta t_d = \mathbf{v}/\cos\theta$ defined in this way may turn out to be greater than the light velocity. In this case the body behaves from the observer's viewpoint like a tachyon. For example, by $\theta \simeq \pi/2$ it passes practically instantaneously finite distances and "grows old" straight away. However, as it was shown in papers [4-7], Lorentz transformations depend on $\mathbf{v}$ but not on $\mathbf{v_d} = d\mathbf{x}/dt_d$, therefore in the multi-temporal world no acausal effects can be observed by transformations to moving reference frames in contrary to true tachyons which, as it is judged by the observer, travel in the new frame backwards in time.

In other words, if some day experimentators discover faster-than-light bodies it will not be obligatory connected with a violation of causality but can indicate on the multi-dimensionality of our world. Particularly, if because of some unknown now reasons the surrounding us region of the universe is an "island" of an one-directed time differing from the "time-arrows" of its adjacent parts, then superluminal astrophysical phenomena have to be observed for very distant cosmic objects [2].

One would hope to bypass the difficulties with the ambiguity of velocity determination by using the so-called radar method which is based on measurements of a time delay of the radar rays reflected by the moving body with respect to the moment of their emission. However, the result is found to be in this case also ambiguous, since the formula used for the calculation of the velocity depends on the time trajectory inclination φ [13].

Propagation of signals

Though all relations are in the multi-time world causal, they are

[2] Such phenomena are observed indeed, however, for the time being one turns out to interpret them all as optical illusions.

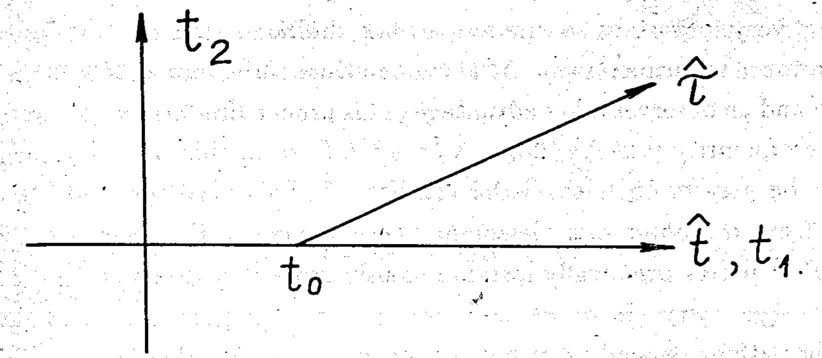

Figure 2: At a moment t_o a splitting of time trajectories of the observer $\hat{t}$ and a luminous body $\hat{\tau}$ occurs. After that $(t > t_o)$ the body becomes invisible.

rather specific in comparison with the one-dimensional ones. In our world luminous bodies remain visible all time while they emit light whereas in the multi-temporal case their luminescence is seen, as a rule, only in some restricted time interval. For example, if owing to the force of some circumstances a splitting of a parallel to the relict axis t_1 time trajectory of a motionless in x-subspace luminous body and the observer's one occurs suddenly (Fig.2), then the body becomes in a moment invisible because it occurs at once in the future with respect to the observer. [3]

The body can remain visible for some time after the splitting only if the observer's trajectory has some inclination θ with respect to the relict time axes [14]. One can see from the Fig.3, that the duration of observing luminescence when the emitted light spreads in the plane (t_1, t_2) from the

[3]Such a behaviors of a luminous body is observed only if time irreversibility is taken into account. In other case the body losing little by little its lustre (displacing into infrared region) remains visible some time even after the splitting [12,13].

past to the future

$$T \equiv (t_f - t_c) = (t_f - t_p) - R/c = \frac{R}{c}\left(\frac{\sin(\varphi + \theta)}{\sin\varphi} - 1\right) \tag{13}$$

Here t_c is the time of the splitting, t_p is the observer's proper time when the light trajectory becomes parallel to the relict axes t_1. When $t > t_f$ the time light signal propagates backward in time t_2. R is the constant distance between the light source and the detector. φ is the angle between $\hat{t}$ and $\hat{\tau}$, θ is the angle of observer's trajectory with respect to the axis t_1.

In a more general case when the luminous body time trajectory *intersects* the observer's trajectory (at the moment $t = t_c$, see Fig.3) the observer sees the luminescence in an interval from t_f when he fixes the ray emitted at right angle to the axis t_1 up to the moment of the last visible signal arrival t_f. For $t < t_s$ the body is too remote in the past and the connection with it is possible only by the help of subluminal signals $(v < c)$. [4] The rays emitted at $t > t_f$ can not be observed owing to the causality principle. In that way, the duration of the visible luminescence expressed throughout the observer's proper time

$$T \equiv t_f - t_s = (t_f - t_c) + (t_c - t_s) = \frac{R}{c}\frac{\sin(\varphi + \theta)}{\sin\varphi}[1 + \cot(\varphi + \theta)] \approx \tag{14}$$

$$R/c\varphi \quad \text{when} \quad \varphi, \theta \ll 1, \tag{15}$$

Here, as in (13), φ is the angle between the trajectories, θ is the angle between the observer's trajectory and the t_1-axis, $t_c$is the time of trajectories intersection. (In order not to complicate our consideration,

[4]Particularly, if sound signals are used, they, obviously, must be emitted at the moment $t_s = t_c/c_s$ where c_s is the sound speed. Only in this case the sound has time to reach the observer.

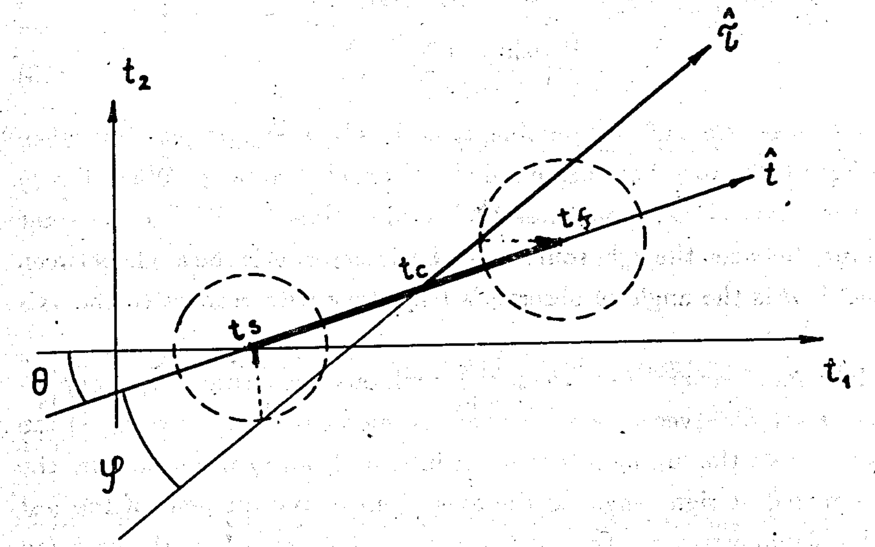

Figure 3: At an observer's proper time t_c the luminous body time trajectory $\hat{\tau}$ is splitted off from the inclined observer's trajectory $\hat{t}$. The luminescence is seen in the interval $t_s \div t_f$. Light spheres $(\hat{t} - \hat{\tau})^2 = (R/c)^2$ from which at different times t the observer can receive signals are dotted. The dotted lines with arrow show the trajectories of the first and last visible signals [14].

we confine oneself by a case when the luminous body and observer's trajectories are disposed on the same plane and the axis t_3 can not be mentioned).

The intersection time measured by means of an "absolute clock" of the relict reference frame $T_1 = T\cos\theta$ and for the observer moving along the axis t_1

$$T = \frac{R}{c}[1 + \cot(\varphi + \theta)] \tag{16}$$

Because the duration of an influence of one body on an other is proportional to their separation, an interaction time of nearly placed bodies is equal practically to zero, i. e. they "see" each other only an instant when their trajectories are intersect and a communication of these bodies is possible only with the help of subluminal signals.

An inclination of a body time trajectory with respect to the observer's one turns out quickly the body from the observer's field of vision even if the luminous body is removed on a comparatively large, macroscopic distance. For example, if $R = 1m$ then a motionless in x-subspace light source with the inclination $\varphi = 1'$, 1°, 40° remains visible, respectively, during 10^{-8}, 4.10^{-7}, 2.10^{-5}s, i. e. the light source becomes practically at once invisible. Only very remote cosmic objects can shine for a long time.

One can show that a observed light frequency $\nu_o = \nu\cos\psi$ where ψ is the time dependent angle between the t-trajectories of the observer and the observing light ray. Therefore, Doppler shift

$$z = [c/\nu\cos\psi - c/\nu]\,/(c/\nu) = |1/\cos\psi - 1| \tag{17}$$

decreases at first up to the value $z = 0$ at the trajectory intersection moment and after that increases up to the initial value $z = 1/\cos\theta - 1$ [12,13].

It can happen that light source and observer's time trajectories are parallel to each other but are displaced on some interval τ (Fig.4). The luminous body is invisible if its distance from the observer $R < \tau/c\sin\theta$.

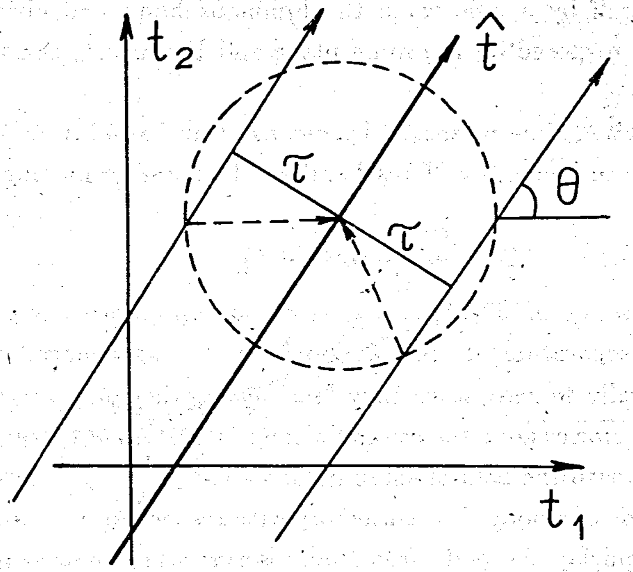

Figure 4: The observer's time trajectory $\hat{t}$ and the trajectories of light sources are parallel each other. The light sphere $(\hat{t}-\hat{\tau})^2 = (R/c)^2$ and the light signals receiving by the observer are dotted.

The luminescence of very remote bodies, as in the one-dimensional case, are observed practically during infinite time.

As we see, in a multi-time world there is a plenty of time displaced invisible bodies around any observer. In this respect such a world is like a hypothetical world of tachyon theories where part of material objects is also inaccessible for observation [15]. In both cases the past and the future co-exist, in fact, with the present. One can suppose that an intersection of t-trajectories of bodies a space distance between which is smaller than their dimensions must result in their destruction.

A duration of the visible luminescence of *a moving* in x-subspace light source depends on a value and a direction of its velocity, however, qualitatively the picture remains the same as in the considered static case. Particularly, if the observer's t-trajectory coincides with relict axis t_1 and the light source moves in x-subspace with zero impact parameter (a head-in-head collision), then the luminescence becomes visible from a moment

$$t_s = \frac{R_s}{c}\tan\varphi = \left(\frac{R_c}{c} + \beta t_s\right)\tan\varphi, \tag{18}$$

where $R_s = R(t_s)$ is the distance of the luminous body from the detector at the moment t_s, R_c is the respective distance at the moment of their t-trajectories intersection ($t = 0$), φ is the angle between these trajectories (Fig. 5A), $\beta = v/c$ is the relative velocity of the luminous body. Solving this equation, we obtain

$$t_s = \frac{R_c/c}{\tan\varphi - \beta}. \tag{19}$$

If at $t = 0$ the source and the detector draw together and the velocity β is small ($\beta < \tan\varphi$, Fig.5A), then the luminescence is seen in an interval from t_s up to $t_f = R_c/c$:

$$T = \frac{R_c}{c}[1 + 1/(\tan\varphi + \beta)]. \tag{20}$$

By increasing of the velocity ($\beta \geq \tan\varphi$) this interval stretches over all left half-axis from $t_s = -\infty$ up to t_f. In the case when at the moment $t = 0$ the light source moves off from the detector and its velocity $\beta < \tan\varphi$ the luminescence is observed, as before, in the interval from t_s up to t_f. However, when $\beta \geq \tan\varphi$ (Fig. 5B) one more interval of the visible luminescence beginning at $t_s = -\infty$ springs up [5].

The asymmetry of the cases of approaching and moving off light source is stipulated by the detector asymmetry with respect to signals

[5] It is clear, if the observation begins at $t > t_s$ then luminescence duration is smaller and by $t > t_f$ the light source remains generally invisible.

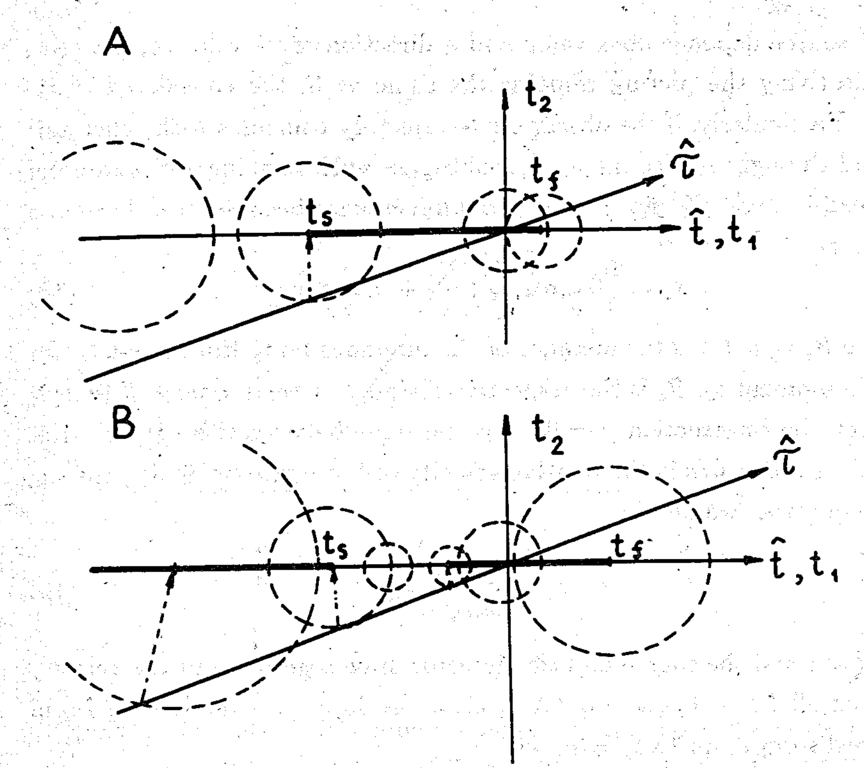

Figure 5: The bold tracks of the axis t_1 are the intervals of visible luminescence of a moving light source. The moment of time trajectories intersection is chosen as $t = 0$. The observer's light spheres are dotted. In case A at $t = 0$ the luminous body with velocity $\beta < \tan\varphi$ comes near to the observer. In case B at $t = 0$ the luminous body with large velocity $\beta > \tan\varphi$ moves from the observer [14].

from the past and the future. If we do not take this circumstance into account, we obtain the expressions for T, calculated in papers [11,12] [6].

As we do not encounter an appearance of material objects "from anywhere" or their disappearance "in nowhere",one may be sure that the time trajectories of all surrounding us bodies are extremely close to each other: ($\varphi = 0$). In particular, the fact of our Sun existence during some milliards of years proves that a deviation of Sun and Earth time trajectories is smaller than a milliardth part of angular second and, in any case, they are far from the intersection point t_c where luminescence anomalies could be observed even by very small angular deviation. Bound systems can exist a long time only when their t-trajectories are parallel to each other.

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[6] In these papers the boundary condition $\gamma^2 \cos\varphi^2 = 1$ (i. e. $\beta = \sin\varphi$) is obtained instead of our $\beta = \tan\varphi$. It is stipulated by the choice as an initial one the moment when the luminous body t-trajectory touches the observer's light sphere what, however, is forbidden usually by the mentioned above principle of time irreversibility [14].

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