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ON EXPERIMENTS TO DETECT POSSIBLE FAILURES OF RELATIVITY THEORY*

by

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ABSTRACT

Two recently proposed experiments by Kolen and Torr, designed to show failures of Einstein's Special Relativity (SR) are analysed. It is pointed out that these papers contain a number of imprecisions and misconceptions which are cleared out. Also the very spread misconception about anysotropy of propagation of light in vaccum in Lorentz Aether Theory (LAT) in analysed showing that the anysotropy is only a coordinate effect. Comparison of the correct results in LAT theory, leading to violation of SR, with new theoretical and experimental results of Torr et al is made. Some of these new results are shown to be incorrect and/or inconsistent with both SR and LAT.

Key-words: Special relativity; Lorentz Aether Theory; Absolute frame; Anysotropy of light.

1. INTRODUCTION*

In two recent papers[1,2], one of them[1] entitled "Misconceptions in Recent Papers on Special Relativity and Absolute Space Theories", D.G. Torr and P.Kolen examine a number of misconceptions and mistakes in recent publications on the differences between a particular absolute space-time theory — the Lorentz's Aether Theory (LAT) and Einstein's Special Relativity (SR). They conclude that all experimental evidences, including that of Mössbauer-Doppler shift experiments (and excluding Marinov's experiment[3]) are equally in agreement with LAT and SR, within current technological detection capabilities. They then propose two experiments in vacuum, which would be appropriate to make this distinction. One of them, the Kolen-Torr clock experiment - is analysed in detail in Ref.(2) and the second - a Doppler shift experiment - is indicated in Appendix D of Ref.(1). Torr et al[4] have actually performed this last experiment. They find agreement with $\Delta\nu/\nu \sim 10^{-16}$, of the form $\sin(2\omega t)$, which they claim[4] agrees with the prediction of LAT according the lines indicated in Ref. (1).

In this paper we analyse these two proposed experiments and show that the Kolen-Torr clock experiment[2] cannot distinguish LAT from SR and that strict LAT cannot lead to the results of Refs.(2,4). We also show that the conclusion[1] that a measurement

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* This paper includes developments of ideas first presented by one of us (JT) in 1980 at a meeting of the "Sociedade Brasileira de Física"[5].

of the one-way velocity of light in vaccum, in inertial frames,has physical meaning in LAT is wrong. Indeed the result depends on the time synchronization procedure used (say Marinov's shaft[3] versus slow transport of clocks[5,6]) and could lead to any number chosen "a priori".

We also refer to two trivial theorems[6] which prove some of these results to be wrong without any computation. We believe that they will help authors and referees to find similar mistakes in future papers.

The rest of the paper is organized as follows: In section 2 we present the definition of LAT followed in this paper and discuss the differences between this theory and SR, clearing out the problem of the one-way velocity of light. We consider strict and extended LAT. In section 3 we discuss the Kolen-Torr clock experiment[2] showing that, done in vaccum, it cannot distinguish LAT from SR. Besides we show that, in LAT or SR, slow transportation of point clocks <u>for arbitrary</u> trajectories is equivalent to Eisntein's method. In section 4 we discuss the Torr-Kolen proposed Doppler shift experiment[1]. We point out imprecisions and misconceptions in their statements and calculations and indicate that strict LAT cannot explain the experimental results of Torr et al[4]. A model[7,9] in extended LAT is, however, in agreement with the experimental findings. Novertheless it predicts twice the value computed by Torr et al[4] following Torr and Kolen[1].

Finally in sec. 5 we present our conclusions.

This paper also contains an Addendum and an Apendix to include comments to the reply of D.G.Torr and collaborators published also in this issue[14].

2. LORENTZ'S AETHER THEORY AND EINSTEIN'S SPECIAL RELATIVITY

Here we follow Ref.[1] as close as possible, in order to limit the ground for discussions, as there is really no consensus and agreement on the definition of LAT. Indeed, Kolen and Torr[1] have not defined LAT and we assume that this theory (not any absolute space-time theory) is characterized by the following assumptions[5-9]:

(i) isotropic propagation of light in vacuum with constant velocity $c(c=1)$ in S_o (some absolute frame, where the aether is at rest) independently of the motion of the source(*),

(ii) time dilation of moving clocks (time T) relative to local time t in S_o (where all clocks are synchronized, say, by light signals (Einstein's method), slow transportation of clocks, rotating shafts (Marinov's method)[3], etc...) given by

$$dT = [1 - v^2 (t)]^{1/2} dt \qquad (1)$$

where $\vec{v}(t)$ is the velocity of the clock as measured in S_o. For constant velocity, eq.(1) reads

$$T(t) - T(0) = (1- v^2)^{1/2} t \qquad (1a)$$

(*) As assumption (i), the following ones are not explicitly stated in Refs.(1,2), but they are used or referred indirectly in the text and are necessary for completeness and consistence.

(iii) Lorentz-FitzGerald contraction of the length of a solid body in <u>translational</u> <u>uniform</u> motion with velocity $\vec{v} = v\hat{e}_x$ (v, a constant) as compared to the length at rest in S_o

$$\delta X_o = (1-v^2)^{-1/2}\ \delta x$$
$$\delta Y_o = \delta y$$
$$\delta Z_o = \delta z \qquad (2)$$

In eq(2), $(\delta X_o, \delta Y_o, \delta Z_o)$ refer to the projections of the solid when at rest in S_o measured at time $t(\delta t = 0)$. $(\delta x, \delta y, \delta z)$ refer to the projections of the body when in motion with velocity $\vec{v}$ in S_o, also measured for $\delta t = 0$, for the same orientation of the body.

Notice that in LAT the contraction of δX_o is real. Also that eq(2) remains valid if $(\delta X, \delta Y, \delta Z)$ are measured in S, at time T, as the measuring rules also suffer the Lorentz contraction. Thus $\delta\vec{X} = \delta\vec{X}_o$.

LAT is characterized not only by (i)-(iii) but also by the underlying assumption.

(iv) There <u>exists at least one</u> internal synchronization procedure by which distant clocks at rest in a frame S (moving with constant velocity $\vec{V} = V\,\hat{e}_x$ relative to S_o) obey

(iv - L) $$T(\vec{x}_1, t) = T(\vec{x}_2, t) = \gamma^{-1}t;\ \gamma^{-1} = (1-V^2)^{1/2} \qquad (3)$$

for any two points with absolute coordinates $\vec{x}_1$ and $\vec{x}_2$, at absolute time t.

This procedure may be provided by Marinov's rotating shaft if Marinov's effect[3] is confirmed as a real phenomenon. Other synchronization relations coexist, however in LAT with (iv - L). Indeed (iv - L) cannot be achieved by Einstein's method, which gives instead of eq(3) the synchronization relation.

$$\text{(iv - E)} \qquad T_E(\vec{x}_1, t) - T_E(\vec{x}_2, t) = - \vec{V}. \ (\vec{x}_1 - \vec{x}_2) \qquad (4)$$

for the phase difference of physical clocks at rest in the moving frame S at different positions $\vec{x}_1$ and $\vec{x}_2$ as seen at time t by S_o observers. Notice that in S_o synchronizations (iv - L) and (iv - E) are identical. (iv - L) is compatible with Marinov's result[3].

SR imposes* besides (i),(ii),(iii), also (iv - E) for any internal synchronization procedure used in S.

In SR the Lorentz contraction is only a coordinate effect (like a projection). Thus equations (2) are also valid in Sr if $\delta\vec{X} = \delta\vec{X}_o$ are measured in S, at time t (with $\delta t = 0$). Instead of (δX_o, δY_o, δZ_o) we use now ($\delta x'$, $\delta y'$, $\delta z'$).

Assumptions (i), (ii), (iii), (iv-E) correspond to the requeriment in SR of invariance of all physical laws under Lorentz transformation (eqs(6) below). Thus LAT considered as a predictive formalism is less restrictive than SR, leaving open the possibility of existence of some non-Lorentz-invariant phenomena.

(*) In SR, S_o has no special significance, being any inertial frame in the class of all inertial frames.

Connected with postulates (i), (ii), (iii), (iv-L) in LAT it is natural, but not necessary to use the Ives-Marinov transformations relating $(\vec{X}, T)$ in S to $(\vec{x}, t)$ in S_o given by

$$X = \gamma(x - Vt); \; Y = y; \; Z = z$$
$$T = \gamma^{-1} t \tag{5}$$

In what follows we call $(\vec{X}, T)$ the Ives-Marinov coordinates gauge (IMG) in S. It is clear that relative to the IMG the propagation of light looks anysotropic even in SR.

On the other hand, with postulates (i), (ii), (iii), (iv-E) the Einstein-Lorentz transformations are more natural but not necessary*, for the coordinates $(\vec{x}', t')$ in the moving frame S (we are using t', from now on instead of T_E). We obtain easily

$$x' = \gamma(x - Vt) \; ; \; y' = y \; ; \; z' = z$$
$$t' = \gamma(t - Vx) \tag{6}$$

We call in what follows $(\vec{x}', t')$ the Einstein-Lorentz coordinate gauge (ELG) in S. It is well known that in this gauge the propagation of light looks isotropic in S even in LAT**. In SR, as is known, eq(4) is usually obtained from the light axiom[9]. Certainly the coordinate gauge of eq(6), as well as ε - synchronized coordinates[11,12] $(0 < \varepsilon < 1)$, can be used both in SR and LAT, and can be obtained by internal synchronization procedures. However, the coordinate gauge of eqs(5), may be used in SR, only by

(*) However as in SR the laws of physics are invariant under the group defined by eqs(6), these transformations are canonical.

(**) This is a consequence of the invariance of the wave equation and Maxwell's equations under (6).

using an external synchronization procedure (in communication with S_o say, looking at the cosmic background radiation). Actually even arbitrary coordinates may be used (for instance Galileu coordinates).

It will be accepted here that LAT predicts nothing different from SR for phenomena involving only the dynamics of point particles and electromagnetic fields in vacuum[5-9]. Thus we need some non-Lorentz invariant phenomenon to be explicitly involved in an experiment designed for detection of failure of SR.

For example in Marinov experiment no twist of the rotating shaft generatrices is assumed to exist in S_o or in S in IMG. There should be an anti-Lorentz (or Marinov) twist in S in ELG, which Marinov claims to have detected. For the Doppler experiment in roto-translating disks such hypothesis in LAT may be that ω is constant in S in IM gauge but not in ELG.

In this paper we shall assume for simplicity, that non-Lorentz invariant effects occur only in the laws of roto-translational motion of solid bodies, which however obey LAT (with the eventual variation (v') given below). Thus only the explicit violation of SR introduced by the laws of rotation can lead to experimental observation of failure of SR. No theory is well defined if such laws are not explicitely stated.

Thus to complete the formulation of LAT in vacuum, we make the following hypothesis[5-9]

(v) The angular velocity of a freely rotating body without translational motion in the moving frame S is constant re lative to either synchronization (iv-L) or (iv-E), this velocity being constant for a freely rotating body at rest in S_o.

Assumption (v) is needed for consistence with the assumption that the only internal synchronization procedures possible in S are (iv-L) and (iv-E) and we shall refer to it as strict LAT. The alternative "or" imply SR in the present context.

We shall consider also, an extended LAT where, instead of (v) we assume:

(v') The angular velocity (ω) of a freely rotating body with constant translational velocity $\vec{V}$ in S_o is constant in S_o.

Notice that ω is here defined by $d\phi/dt$, $\phi(t)$ being the angle of the radius vector $\vec{r}(t) - \vec{V}t$ with $\vec{r}(0)$ for a given point, of the rotating solid as seen from S_o.

In Refs. [1,2], as in most of the papers on the subject, no explicit definition of the constant angular velocity used is given. We include here the form (v') due to the possibility that it may have been implicitely used in these papers. It is clear that (v)+(iv-L) and (v') contradict SR which imposes that in S the angular velocity is constant in ELG.

3. THE KOLEN-TORR CLOCK EXPERIMENT IN VACUUM

In the Kolen-Torr proposed clock experiment[2] two rubidium frequency standards of the same known period are placed a distance D appart (as measured in the moving frame S), the whole system moving with constant velocity $\vec{V}$ relative to S_o. This is shown in Fig. 1(*), where A and B represent the two clocks at t = 0 (position 1) in a table moving with velocity $\vec{V}$, which may rotate slowly so to bring the clocks to the situation B'A' at $t=t_o$ (position 2).

Actually, as D = 300m, the moving table is not introduced in their final proposal[2], the rotation being provided by the earth.

No attempt is made by them to synchronize the clocks when they are appart. However they assume that the frequency of the clocks are perfectly stable, so that there is no drift in their relative phase, i.e., that the phase difference ΔT of the clocks remains constant when they move from position 1 to 2.

We shall show that the last assumption is wrong and when the correct computation is made (no Einsteinian Relativity implied!) a cancellation of the time delay obtained in Ref[2] occurs**. To understand this point let us first obtain the correct results.

In the experimental arrangement shown in Fig.1 a signal from clock A is used to trigger the start input at $T = T_A$ (clock A time) of an interval counter located at clock A itself. A signal from

(*) We notice that in Fig.1 (seen from S_o) the circle should be Lorentz contracted in the direction of $\vec{V}$.

(**) A preliminary version of these results is given in Ref(6).

clock B conveniently prepared is fed to the stop input of the counter at $T = T_A'$. The counter registers the time interval $\Delta T_{A_1} = T_{A_1}' - T_{A_1}$ (see Fig. 2) in situation 1.

Assuming that $\vec{V} = V\hat{e}_x$, the velocity of the S-frame as measured in S_o, is in the plane of the table we have for a point in the disk ($\vec{r} = \vec{r}_o + \delta\vec{r}$)

$$\vec{v}(t) = \vec{V} + \frac{d\delta\vec{r}}{dt} = \vec{V} + \delta\vec{v}(t) \tag{7}$$

Notice that $\delta\vec{v}(t)$ is measured in the frame S_o, <u>not</u> in S, and $\vec{r}_o$ is the radius vector of the center of the table. Also,

$$\vec{r}_{AB}\cdot\hat{e}_x = d(t)\cos\theta(t) \tag{8}$$

where

$$\vec{r}_{AB} = \vec{r}_B(t) - \vec{r}_A(t) \tag{9}$$

is the radius vector from A to B (all quantities being referred to S_o). In what follows we are interested in the limit $\delta\vec{v} \to 0$.

If we take $t_B = 0$ at the time clock B sends its signal (Fig2), then the transit time for light to reach A is $t_A - t_B = t$, which is given from $t^2 = d^2 + v_A^2 t^2 - 2dv_A t\cos(\theta+\delta\theta) + 0(\delta\vec{v}_A)$ or

$$t = \gamma^2 d(\sqrt{1-v_A^2(t)\sin^2\theta'} - v_A(t)\cos\theta') + 0(\delta\vec{v}_A) \tag{10}$$

with $\theta' = \theta + \delta\theta$.

The term $0(\delta\vec{v}_A)$, which vanishes with δv_A in eq(10) came from the assumption that the transit time t is small enough so that

$t\left|\frac{d\delta\vec{v}}{dt}\right| << |\delta\vec{v}|$, a satisfactory condition.

Due to the smalleness of $\delta\vec{v}$ and $\delta\theta$ we may write eq(10) as

$$t = \gamma^2 d(\sqrt{1 - V^2 \sin^2\theta} - V\cos\theta) + 0'(\delta\vec{v}_A) \tag{10a}$$

Thus, from eqs(1) and (10a)

$$\Delta T_{A_1} = \Delta T + \gamma^{-1} t = \Delta T + \gamma d(\sqrt{1-V^2 \sin^2\theta} - V\cos\theta) + 0'(\delta\vec{v}_A) \tag{11}$$

If the table is rotated by 180°, or, as in the Kolen-Torr proposed experiment, "twelve hours" rotation is made by the earth, in S_o, the clocks positions are interchanged (situation 2 in fig1). Thus if the experiment is repeated again the time interval recorded by the counter (located at A') will be

$$\Delta T_{A_2} = \Delta T + \gamma d\ (\sqrt{1 - V^2 \sin^2\theta} + V\cos\theta) + 0(\delta\vec{v}_A) \tag{12}$$

Thus we find for $\delta\vec{v} \to 0$

$$\Delta T = \Delta T_{A_1} - \Delta T_{A_2} = -\ 2\gamma\ Vd(t)\ \cos\theta(t) \tag{13}$$

which for $\theta = 0$ gives, using eq(1)

$$\delta t\ (\theta = 0) = -2VD \tag{14}$$

which coincides with eq(9) of Kolen-Torr[2], although their reasoning is misleading. Here the initial phase difference (ΔT) cancelled due to their hypothesis.

In order to show that the phase difference does not remains constant, consider the clocks A and B, which at $t = 0$ (in S_o) have radius vectors $\vec{r}_A(0)$ and $\vec{r}_B(0)$ (in S_o).

During the rotation of the table (or the earth) the clocks A and B are moving with variable velocity $\vec{v}(t)$ [eq(7)].

$$\vec{v}_A(t) = \vec{V} + \delta\,\vec{v}_A(t)\ ;\ \vec{v}_B(t) = \vec{V} + \delta\vec{v}_B(t) \tag{7'}$$

The times registered by the clocks A and B and the time t in S_o are related by

$$T_{\substack{A\\B}}(t) = T_{\substack{A\\B}}(0) + \int_o^t dt\{1 - (\vec{V} + \delta\vec{v}_{\substack{A\\B}}(t))^2\}^{1/2}$$

$$= T_{\substack{A\\B}}(0) + t(1 - V^2)^{1/2} - (1 - V^2)^{-1/2}\vec{v}.\int_o^t \delta\vec{v}_{\substack{A\\B}}(t)dt + 0(\delta\vec{v}^2_{\substack{A\\B}}) \tag{15}$$

Thus for very slow (clock) motions $(\delta\vec{v}_{\substack{A\\B}} \to 0)$

$$T_B - T_A = \Delta T - (1-V^2)^{-1/2}\,\vec{v}\,.\int [\delta\vec{v}_B(t) - \delta\vec{v}_A(t)]\,dt$$

Now

$$\vec{r}_{AB}(t) = \int_o^t (\delta\vec{v}_B - \delta\vec{v}_A)dt$$

and we have

$$\Delta T(t) = T_B - T_A = \Delta T - (1-V^2)^{-1/2}\,\vec{V}.\vec{r}_{AB}(t) \tag{16}$$

Eq(16) shows that the relative phase of the clocks is not constant, contrary to the Kolen-Torr assumption. As the clocks A and B move to new position they will be out of phase not by ΔT but by

$$\Delta T' = \Delta T - (1-V^2)^{-1/2}\,d(t)\,\cos\theta(t) \tag{17}$$

valid in the limit $\delta\vec{v} \to 0$.

Thus, even if they were synchronized at $t = 0$, with $\Delta T = 0$, they would be out of phase as the table (earth) rotates, for S_o ob servers, at time t.

It is clear that for symmetric trajectory as the FitzGerald--Lorentz contracted disk*

$$\delta\vec{r}_{\substack{A\\B}}(\theta) = -\delta\vec{r}_{\substack{A\\B}}(\theta+\pi) \tag{18}$$

where θ is the angle of rotation of the table. In the case of the Kolen-Torr proposal θ corresponds to situation 1 in Fig.1 at t = 0, and $\theta+\pi$ corresponds to situation 2 in Fig.1, at $t = t_o$.

We conclude that the correct equations for the intervals of time registred by the time counter are

$$\Delta T'_{A_1} = \Delta T + \gamma V\, d\cos\theta + \gamma d\,(\sqrt{1 - V^2\sin^2\theta} - V\cos\theta)$$

$$\Delta T'_{A_2} = \Delta T - \gamma V\, d'\cos\theta + \gamma d'\,(\sqrt{1 - V^2\sin^2\theta} + V\cos\theta) \tag{19}$$

with $d = d(\theta)$ and $d' = d(\theta+\pi)$.

Thus,

$$\Delta T'_{A_1} = \Delta T'_{A_2} = \Delta T + D\sqrt{1 - V^2\sin^2\theta} \tag{19'}$$

where D is the AB distance measured in S and we use d = d'. Then, the difference of total time registrations of the counter is (for $\delta\vec{v} \to 0$)

$$\delta T' = \Delta T'_{A_1} - \Delta T'_{A_2} = 0 \tag{13'}$$

a null result, valid to all orders of V in the limit $\delta v^2 \to 0$.

(*) We assume that in LAT a rotating disk in S has the same shape in ELG (or IMG) as a non rotating disk at the same position, or that, at most, it has some contraction in the $\vec{V}$ direction, thus respecting equ. (18).

Notice that eq(13') is valid even if D changes with time with the only restriction given by eq(18).

We like to mention here that the result $\delta T' = 0$, which coincides with the prediction of SR, is a consequence of Theorem I of Ref. (6) which states that in the limit $\omega \to 0$ predictions of (strict) LAT are identical to those of SR.

We close this section with the proof of the remark that time synchronization by slow transportation of clocks is equivalent to Einstein's method. For this it is enough to observe that the result expressed by eq (16), which is valid for arbitrary transportation trajectory, is identical to eq(iv-E) which is the synchronization relation resulting from Einstein's method.

4. THE ROTOR DOPPLER SHIFT EXPERIMENT

Torr and Kolen(1) analyse a rotor Doppler shift experiment where source and detector are attached to two points of the rim of a rotating disk and propose an experiment where these positions have small angle separation.

The calculations presented are misleading in several aspects. First, Kolen-Torr state that the disk is rotated at an angular velocity Ω. No mention is made to the system in which Ω is defined (S_o or S?) as to the coordinate gauge used for the measurement of such a velocity (IMG, Galilean, or ELG) if in S. This is a serious imprecision, if not a misconception.

Then we first assume that these authors (1) were implicitly adopting our hypothesis (v), i. e., Ω must be constant either in IMG or in ELG, but not in S_o. If Ω is constant in ELG no breakdown of Lorentz invariance can be observed[6]. This is obvious because, according to the discussion in section 2, there is no non-Lorentz invariant phenomenon explicitly involved.

We have shown[7] that if a violation of SR occurs in LAT (according to (v)), i. e., Ω constant in IMG, then the result for $\Delta\nu/\nu$ is

$$\frac{\Delta\nu}{\nu} = \frac{D}{R}\,(\Omega^2 R^2)\ V\cos\Omega t \qquad (20)$$

(R being the earth's radius) which for the specific Torr et al[4] experiment ($D/R \sim 10^{-4}$) gives $\Delta\nu/\nu \sim 10^{-19}$ in disagreement with the theore tical results of Ref [4].

Second, Kolen-Torr use the wrong addition of velocities (their eqs. (D2) - (D4)). Indeed they add $\vec{V}$ measured in S_o with $\vec{u}_a$ or $\vec{u}_e$ measured in the S-frame. However, they do not specify relative to which coordinate gauge $\vec{u}_a$ and $\vec{u}_e$ are measured in S. In LAT (with (v)) they could have used IMG or ELG in S thus leading in both cases to a law of addition of velocities in S_o obviously <u>different</u> from their equations (D2) - (D4). Besides they do not use in S_o the Lorentz contraction of the disk or eventual aberration effects. This leads to an additional contribution which cancels the main term in Ref[4] if they are in the case of strict LAT which, we consider to be the case.

As a consequence of the errors mentioned above their formula for the Doppler-shift is not valid in (strict) LAT. Thus, the computation of the Doppler shift experiment with small angular separation made by Torr et al[4], based on the equations of Ref[1] must be wrong (in <u>strict</u> LAT).

Indeed our eq(20) valid for strict LAT cannot agree with Torr et al[4] computations which lead to the results $\Delta\nu/\nu \sim 10^{-16}$ with a second harmonic variation.

<u>We now assume that</u> K-T used hypothesis (v') that the angular velocity of the disk is constant in S_o, or in S for Galilean comoving coordinates, thus departing from both (strict) LAT and SR, as is clear from section 2. Now the equations D(1,2) of ref[1] are correct. In ref[7] we obtain in a very simple calculation (in S and in ELG) devoid of eventual corrections for contraction or aberration effects[5], for a disk circular in S (ELG) or when at rest in S_o:

$$\frac{1}{\Omega R}\,\frac{\Delta\nu}{\nu} = \frac{D}{R}\left(-V^2\sin 2\Omega t + \Omega R\, V\cos\Omega t\right) \tag{21}$$

valid in E-LAT.

The equation obtained by Torr et al[4] gives for $\Delta\nu/\nu$ a result equal half the value of the first term in eq(21). The prediction for $\frac{\Delta\nu}{\Omega}$ of eq(20) agrees with Theorem I for (strict) LAT as it vanishes (as in SR for any Ω) in the limit $\Omega \to 0$. Notice that the contribution for $\Delta\nu/\Omega$ of the first term of eq(21) is finite in the limit $\Omega \to 0$. However Theorem I is not valid for extended LAT.

Also, if this is the case (LAT), we find mistakes or misconceptions in ref[1] and possibly in [4]. Indeed they did not mention any use of Lorentz-FitzGerald contraction in S_o and aberration effects for observations made in S. This must be the source of the error in computations of ref[4] if they used extended LAT, as compared with ours which have been carefully checked[8]. Notice that Eq. (16), has a leading term compatible with observations of ref.[4].

We finally mention the trivial Theorem II of Ref. [6] which states basically that "unless the properties of free roto-translating solid bodies are explicitely defined in a way that assures that the angular velocity ω_L in S and ELG changes with time no violation of SR can be obtained" in a correct calculation in vacuum. Indeed we must then assume ω_L = constant which is SR.

4. CONCLUSIONS

In this paper we analysed recently proposed experiments by Kolen-Torr designed to show failures of Einstein's Special Relativity. We found that their clock experiment[2] cannot distinguish between LAT and SR. Also we pointed out imprecisions and misconceptions in the calculations of their proposed Doppler-shift experiment[1]

We make it clear that LAT with hypothesis (v) cannot predict the experimental results found by Torr et al[4], although these results can be predicted[7,8] in a generalised LAT (with hypothesis (v')).

We would like to emphasize here that Marinov's experiments[3] and Torr et al[4] experiment are the only ones, to our knowledge, capable of showing failure of SR. They are both based on the new hypothesis, never tested before, that the roto-translational motion of solid bodies violate Lorentz-invariance. So, despite our criticisms* we praise very much the theoretical and experimental efforts of Kolen--Torr[1,2] and Torr et al[4] to find an answer to the old issue of absolute versus relative motion. In any case if both Marinov and Torr et al experiments are correct (and have no further explanation) they have succeeded in proving that roto-translational motion of solid bodies do violate SR.

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*Also despite our criticism to T-K analysis[1] of Doppler experiments with source and detector in opposite radii of the rotating disk a correct calculation confirms their conclusion that SR violating effects in this case are out of experimental reach to this date[8].

ADDENDUM

Due to the fact that the, long delayed, publication of this paper was tied to the publication of the following paper by D.G. Torr and collaborators[14], to be referred as C, this Addendum is included. Coments and further conclusions show that also their reply[14] is not free of mistakes and misconceptions. We first show that their theory in vacuum corresponds to our strict LAT. Indeed they use postulates (i) - (iii) and take Ω = constant in the co-moving Lorentz contracted frame with the universal time T. This is LAT in I.M. frame. Then, contrary to their conclusions, $\Delta\nu/\nu$ gives no term $V^2\omega R \sin^2\omega t$ (in strict LAT), for the Doppler rotor experiment. As a contribution of this type was found in the experiment of Gagnon et al[15] this experiment leads to the violation of both LAT and SR (if correct).

Also an Appendix was added to the present paper, to include the details of our computations for Doppler rotor experiment in LAT[7].

Now we make the following comments:

1) Torr at al[14] state that in ref.[2] attention was already called to the fact that Kolen-Torr prediction[2] for the clock experiment (eq. (14) in this paper) is wrong. Actually their "Note added in proof" only states that "the result is smaller". It is not clear what this means. It might be a numerical factor...

The reason for our analysis is not to insist in their mistake, but to clear up misconceptions and the origin of mistakes which appear in several papers. This task is not performed in C as, although the expression for the clock experiment in vaccum now va nishes, it is not shown why.

2. After eq.(19)-C, besides the wrong affirmation that we "asserted that STR addition of velocities must be used" in K.T. computations [4], there is a further statement which is a misconception about SR: "STR is a descriptive theory which provides the transformation equations between two coordinate systems. It does not concern itself with the underlying physics". We have exhaustively showed that co ordinate systems are irrelevant[5-9]. Besides, we showed that SR is a special case of LAT and thus has stronger physical limitations then LAT.

3. Indeed, as referred in C, in sec.4 of the present paper we state that Kolen-Torr use "the wrong addition of velocities (their eqs. (D2)-(D4)". This statement was made because they did not indi cate at any stage the use of Lorentz contraction (eq.2-C) in their computations. Thus we assummed that they were using IMG, as stated in sec. 4. Therefore, they should have used Marinov's[15] law of addition of velocities. Our assumption is explicitly confirmed in C in the sentence which follows eq. (20-21)-C stating[14] that these galilean equations are true "because contracted rods and re tarded clocks are used to measure the velocities $\vec{u}_s$ and $\vec{u}_r$". This is clearly wrong. Actually the correct way to proceed in order to save most of the theoretical work of C, if galilean coordinates are used (and then (20-21)-C are valid), is to explicitely introduce the Lorentz contraction. Then $|\vec{r}(t)| \neq$ constant, the rotating disk

being eliptical. The correct expression for $\vec{u}$ would result different from $\vec{\omega} \wedge \vec{r}$ they use. Also $|\vec{\omega}(\psi)|$ is not constant in galilean coordinates as they assume $|\vec{\omega}|$ and $|\vec{r}|$ to be constant in Ives-Marinov coordinates. Besides there is an abberration effect.

Instead of working with galilean coordinates it would be much simpler to use the IMG. Indeed Marinov did this computation finding results[15] compatible with ours and in desagreement with C.

Finally the simplest procedure is to work in ELG[5-9] as we have done in the Appendix and in Refs.[6-9].

4. The alternative (v') of ELAT (extended-LAT) was introduced in sec.4 because we imagined that Torr et al[4] might have imposed constant $\vec{\omega}$ in the <u>absolute</u> frame S_o.

Here, instead of the result[14] of C

$$\frac{\Delta\nu}{\nu} = \frac{1}{2}\Omega D\, v^2 \,\mathrm{sen}2\,\Omega t \qquad \text{Equ.(44)-C}$$

which does not exist in LAT, we find in ELAT[8] the same equation with a factor 2 as stated in the text. However it has been proved by one of us (JT) that ELAT disagrees with other experiments[9].

5. In equ.(26)-C, $\frac{\Delta\nu}{\nu}$ is taken as $\frac{\Delta\nu}{\nu_o}$, when measured in S_o. Actually they should have taken, instead:

$$\frac{\Delta\nu}{\nu} = \frac{\nu'_r - \nu_r}{\nu'_r}\,, \quad \nu'_r = \nu_o\sqrt{1 - v_r^{\,2}/c^2}\,,$$

as the equation is valid in S_o where the intrinsic frequency of the absorber is ν'_r. Thus, together with (25)-C they would obtain in S_o (in vacuum)

$$\frac{\Delta\nu}{\nu} = 1 - \frac{\nu_r}{\nu'_r} ,$$

with:

$$\frac{\nu_r}{\nu_r'} = \frac{\nu_a}{\nu_e} = \frac{\sqrt{1 - V_s{}^2/c^2}}{\sqrt{1 - V_r{}^2/c^2}} \quad \frac{1 - \vec{V}_r.\hat{n}/c}{1 - \vec{V}_s.\,\hat{n}/c} \tag{i}$$

Equ.(i) is exactly our equation (1.A), (in the appendix) which, we stated[6], is valid also in LAT[7-8].

The main difference in our procedure is that, as we work with Einstein-Lorentz coordinates, equ.(i) is also valid in the comoving inertial frame and we do not have to go through complicate calculations. Thus equ.(26-C) is also incorrect (in S_o).

6. A further contradiction exists between equation (44)-C and results obtained by Maciel and Tiomno[8]. Indeed equation (20) of the present paper is still valid[8] for the diametrally opossed arrangement of the Gagnon et al[16] experiment, in strict LAT. Now D in equ.(20) is the tangencial displacement of the absorber from the other extreme of the diameter. Therefore, as said before (strict) LAT predicts an exactly zero result even to order $V\,\omega^2 R^2 \cos\omega t$ for exact opposition of source and absorber, and not one of the order 10^{-14} of the type $V^2\,\omega R \cos 2\omega t$ as found experimentaly[14]. Therefore, if the interpretation[14] of the Gagnon et al experiment is correct it disproves both SR and (strict) LAT. Also the experimental result is 10^{-2} of the one given by the theoretical result of Torr et al[14] for $V \sim 300$ Km/s.

7. One or both equations (47)-C and (48)-C supposed to be valid, respectively for S.R. and LAT, must the wrong. Indeed they are not identical. However they should be valid in S_o or if $\vec{V} = 0$. But as no constraint between $\vec{u}_s$, $\vec{u}_r$ was used in the derivation of these equations LAT must be identical to SR in this prediction as no Lorentz violating property was used.

8. It is very strange that for the analysis of the Gagnon et al experiment equ. (44)-C was not used. Actually it would lead to

$$\left(\frac{\Delta\nu}{\nu}\right)_i = - v\, V^2 \text{ sen } 2\psi_i \qquad (v = \omega R). \tag{ii}$$

Then, going back to equ. (26)-C, Torr et al[14] discard a number of terms and deduce equation (75)-C which can be written

$$\left(\frac{\Delta\nu}{\nu}\right)_i = - v\, V^2 \cos 2\psi_i + v\, V^2. \tag{iii}$$

This equation is used to obtain the value of R.A. in agreement with other investigations. The previous expression would lead to a result 90^o apart.

9. Fig. 14 in C, which includes besides a spurious constant effect (∿ 270 Khz) a sin ωt term adjusted to the M-LAT theory, is strikingly similar to a figure recently presented[9] by one of us (J.T.). There[9] it was shown that Jaseja et al[19] experiment may have included evidence of violation of SR according to the results of Maciel and Tiomno[8] for the sin ωt time dependence of the laser

characteristic frequency (LAT in vacuum).

It was shown[9] that in the Jaseja et al[17] experiment, which involves two idential masers, one beam at an angle ψ and the other at $\psi + \pi/2$ with the West-East direction, the frequency shift $\Delta\nu(\psi) = \nu_1(\psi) - \nu_2(\psi + \frac{\pi}{2})$ suffer a change $\delta\nu = \Delta\nu(\psi) - \Delta\nu(\psi+\pi/2)$, when the system is rotated by $\pi/2$, given by:

$$\delta\nu = -2\alpha\nu\ \omega R_E\ V\ \cos\theta_L \cos 2\psi\ \cos\omega t, \qquad \text{(iv)}$$

besides a cosntant spurious effect $\delta\nu_o$.

Here ωR_E is the equatorial velocity of the earth, θ_L the latitude, and $t = 0$ is the moment when $\vec{V}$ (in the plane of the equator) becomes paralell to the West East direction.

The factor α introduced in (iv) to measure the fraction of anchoring of the table to the earth. Indeed as in Jaseja et al experiment[17] the table is suspended by a rod with torsion oscillation period of 20 sec and is at rest in the two extreme positions only instantly, it is possible that it may aquire the earth's deformation in E-W direction only partially. It was assumed[9] that according to Smoot et al[18] the RA of V was 12 hr. Then the minimum of (iv) should have occurred at 6 hr sideral time, or 10 hr local time, on January 20, 1963, leading to $(\Delta\nu/\nu)_{max} \cong 10^{-10}$. This leads, from equ. (iv) to:

$$\alpha \cos 2\psi \sim 5.10^{-2}$$

It was[9] strongly suggested that the experiment of Jaseja et al be repeated with the table at rest and $\psi = 0$ so that $\alpha \cos 2\psi = 1$ which should lead in LAT to $\frac{\delta\nu}{\nu} \sim 10^{-9}$. We mention also that this is not a one way but a <u>round trip</u> effect as light travels the distance D between the mirrors many times ($\Delta\nu/\nu \sim \Delta D/D$).

10. In this paper we concentrate in vacuum experiments. Thus we do not analyse the equations supposed to be valid in material media[14]. It is clear however that a number of terms must be wrong in C also in the general case (M-LAT) as the limiting value of these terms (above mentioned) in vacuum is wrong. The term which originates the prediction for the K-T clock experiment may be correct as it has the right vacuum limit (zero). However their experimental result disagree with Trimmer et al[19].

In conclusion, we still maintain that the results of references [1,2], [4] and [14] that we analyse in this paper are wrong in LAT and that our straighforward corresponding results are correct.

However it is very important to mention that what is proved in C is that the experimental results of a number of papers when analised with empirical equations lead to an absolute velocity of the laboratory relative to the preferential S_o frame which agrees with results obtained from the cosmic background radiation asymmetry as well as from Marinov's experiment, although sőme of them disagree with both SR and (strict) LAT.

Finally we like to mention that besides Marinov experiment, the Torr et al[14] experiments as well as the Jaseja et al[17] one may indeed lead to the conclusion that S.R. is violated. Experiments of these types should be encouraged to clear up the situation on this respect. However, except in Marinov experiments the errors are still so large that agreement with S.R. is not excluded.

APPENDIX

CALCULATION OF THE DOPPLER EFFECT IN THE ELG (LABORATORY)

Taking advantage of the fact that the ELG can be used in both LAT and SR, in all inertial frames[5,6], and that Maxwell equations in S have the same form in this gauge both in S_o and S, we obtain in what follows a formula for the Doppler shift using the ELG; in vacuum.

The Doppler shift experiment is a comparison of the emitted and absorbed wave-lengths (or frequencies) of a monocromatic radiation. We have (no SR imposed!), valid in any inertial frame in ELG;

$$\frac{\nu_e}{\nu_a} = \frac{\lambda_a}{\lambda_e} = \frac{\gamma_e}{\gamma_a} \frac{1 - \vec{k}.\vec{v}_e}{1 - \vec{k}.\vec{v}_a} \qquad (1.A)$$

In eq (1.a), the λ's are wave-lengths, ν_e and ν_a the frequencies as measured respectively in the emitter's rest frame (ν_o) and the absorber's rest frame, the $\vec{k}$ is Maxwell's propagation unit vector, and $\gamma_{(e/a)}$ are Lorentz's factors associated with the respective velocities $\vec{v}_{(e/a)}$.

Eq. (1.A), identical to the relativistic expression, is valid in any inertial frame for ELG as it involves only the Lorentz invariance of Maxwell's equation in vacuum (in ELG) and the properties of point atoms. This equation is *valid* even if some non Lorentz-invariant phenomenon is also involved, which in this paper we restricted to the properties of the roto-translational motion of the solid body (tre rotating disk) where source and detector are attached. Thus we do not consider here possible violations particular this is the equation used in ref [7.8].

In the laboratory S eq (1A) reads

$$\frac{\nu_e}{\nu_a} = \sqrt{\frac{1 - v_a^2(t+\delta t)}{1 - v_e^2(t)}} \cdot \frac{1 - \vec{k}\cdot\vec{v}_e(t)}{1 - \vec{k}\cdot\vec{v}_a(t+\delta t)} \qquad (2.A)$$

In eq (2.A) t is the emission time and $t + \delta t$ the absorption time as measured in S in the ELG, were $\vec{k}$ is the unit vector in the direction

$$\vec{r}_a\ (t + \delta t) - \vec{r}_e\ (t) \qquad \text{(see fig. 3)}$$

We now approximate eq (2A) for the situation of Kolen-Torr proposed experiment[1]. We have $2\alpha = \Delta\psi \cong 10^{-4}$ for the angular separation of source and detector at time t and $\cos\alpha \cong 1$. Here the disk is assumed to be circular in the laboratory in the ELG

$$\begin{aligned} \hat{k}\cdot\vec{v}_e &= v_e \cos\alpha_e \\ \hat{k}\cdot\vec{v}_a &= v_a \cos\alpha_a \\ \alpha_a &= \alpha_e = \alpha \end{aligned} \qquad (3.A)$$

Writing

$$v_{\binom{e}{a}}(t) = R\,\Omega_{\binom{e}{a}}(t) \qquad (4.A)$$

where R(const.) is the disk's radius and $\Omega_{\binom{e}{a}}(t)$ is the angular velocity of source and detector at time t we have,

$$\Omega_a(t+\delta t) = \Omega_e(t) + \delta\omega \; ; \; \delta\omega << \Omega_e \tag{5.A}$$

from eq(9) we get for $\frac{\Delta\nu}{\nu} = \frac{\nu_a - \nu_e}{\nu_e}$

$$\frac{\Delta\nu}{\nu} = - R\delta\omega$$

$$= -R\Omega'\Delta\varphi \; ; \; \Omega' = d\Omega/d\varphi \tag{6.A}$$

where $\theta = \Delta\varphi$ is the angular separation between emitter and absorber.

We now analyse the specific case of the Kolen-Torr doppler shift experiment. We assume the rotation velocity to be uniform in the laboratory in Ives-Marinov-Gauge, i.e., we write

$$\varphi_M - \bar{\varphi} = \omega T = \omega\gamma^{-1} t_a \tag{7.A}$$

This corresponds to LAT (strict).

Using again eq(5.A) and the fact that $\varphi_M = \varphi$ (where φ is the angle measured in ELG) we have

$$\Omega(t) = \frac{d\varphi}{dt} = \omega/(1 + \omega r V \sin\varphi(t)) \tag{8.A}$$

For $V << 1$ we approximate eq(8.A) as

$$\Omega(t) \simeq \omega - \omega^2 r V \sin\varphi \tag{9.A}$$

Equs. (4.A) and (8.A) show that $v_{(e_a)}$ depends on the angular coordinate $\varphi_{(e_a)}$. For the experiment of Ref(4) we then get, from eq (6.A) and eq (9.A), using $\Delta\varphi \simeq d(1+\omega R)/R$, where d is the distance between source and detector

$$\Delta\nu/\nu \simeq \frac{d}{R}(\omega^2 R^2) V \cos\varphi \qquad (10.A)$$

Notice that eq (8.A) for Ω/ω is in agreement with Theorem I of Ref. (5) as it tends to 1 in the limit $\omega \to 0$, as in SR. Also from equ (10.A); $\frac{\Delta\nu}{\omega} \to 0$ for $\omega \to 0$ as in SR.

The result for $\Delta\nu/\nu$ for extended LAT (hypothesis v') is obtained in ref. [7] for R constant in ELG. The general treatment of rotor Doppler experiments and others, both for R = const and for R = R(ψ) in the comoving frame, was made in ELG by Maciel and Tiomno[8].

CAPTIONS OF FIGURES

FIG. 1 - Schematic View of the Kolen-Torr Clock Experiment in vacuum.

FIG. 2 - Motion of the Clocks Relative to S_o (K- T Clock Experiment).

FIG. 3 - The Rotor Doppler Shift Experiment as seen in the moving frame S in the E.L.G. The absolute frame S_o has velocity $-\vec{V}$.

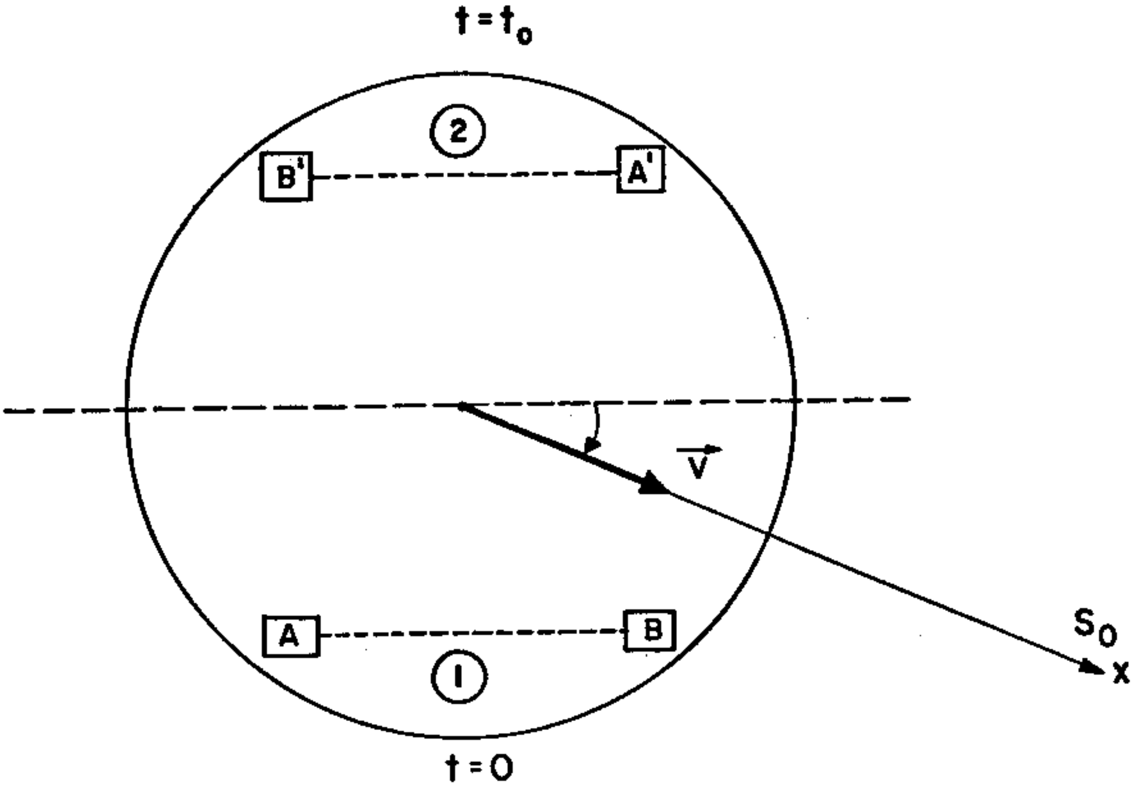

Fig. 1

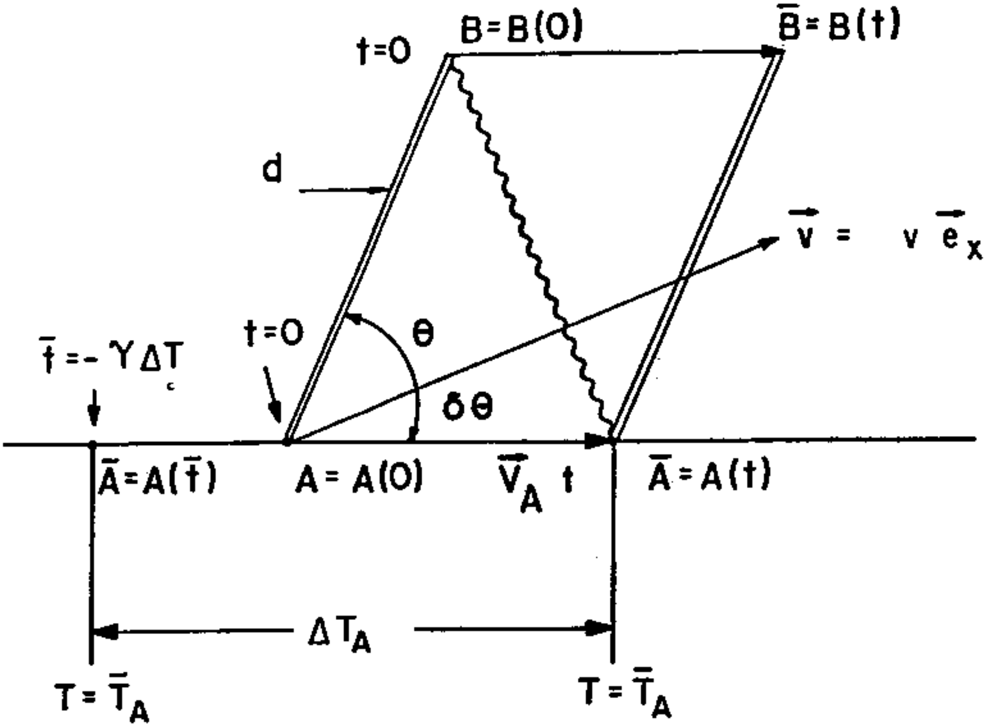
t=0
B=B(0)
$\bar{B}$=B(t)
d
$\vec{v}$ = v $\vec{e}_x$
t=0
θ
$\bar{t}$=- γΔT
δθ
$\bar{A}$=A($\bar{t}$)
A=A(0)
$\vec{V}_A$ t
$\bar{A}$=A(t)
ΔT_A
T=$\bar{T}_A$
T=$\bar{T}_A$

Fig. 2

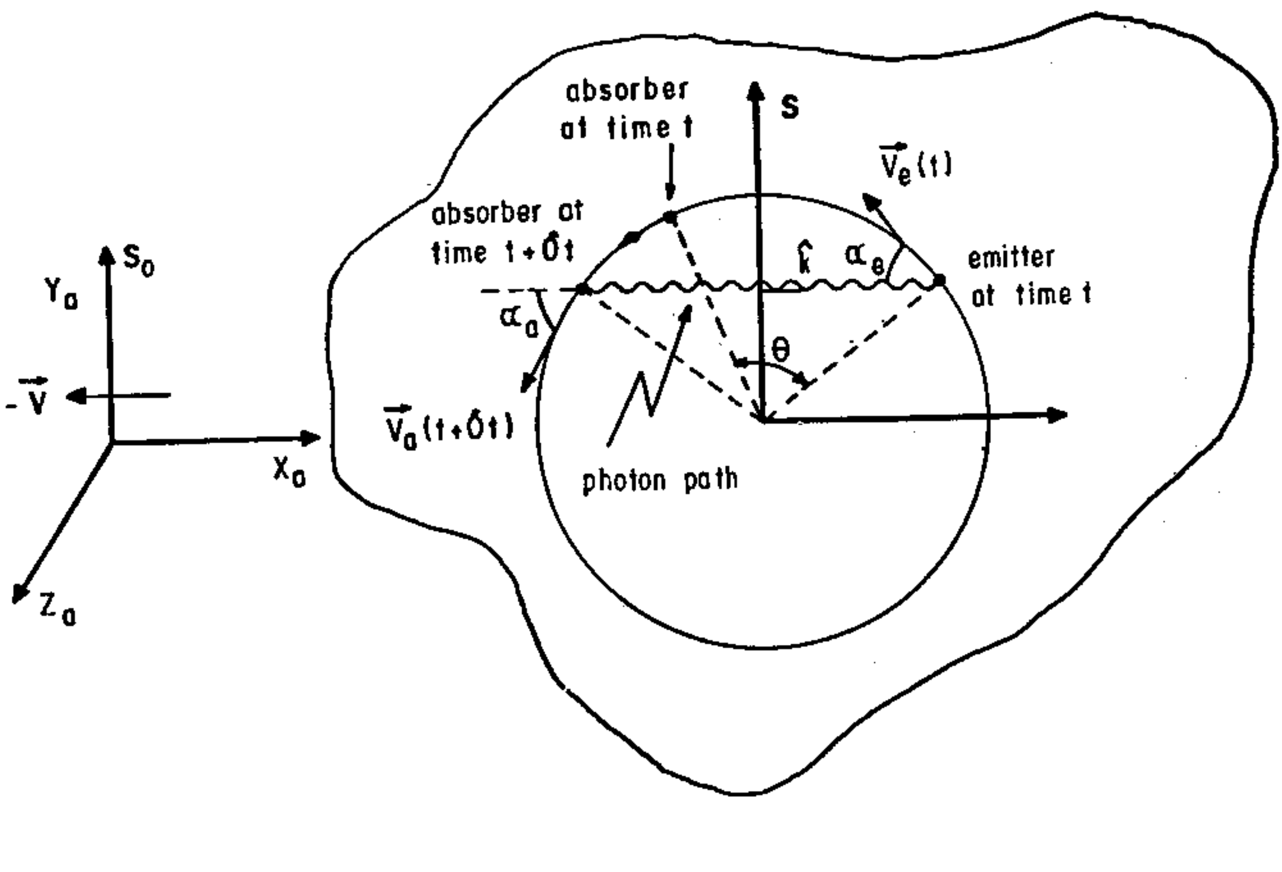
absorber
at time t
absorber at
time t+δt
S
$\vec{V}_e(t)$
$\hat{k}$
α_e
emitter
at time t
S_0
Y_a
α_a
θ
$-\vec{V}$
$\vec{V}_a(t+\delta t)$
X_a
photon path
Z_a

FIG.3

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