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EINSTEIN'S SPECIAL RELATIVITY VERSUS LORENTZ'S AETHER THEORY*

by

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Abstract

We examine in this paper conditions under which we may expect failure of Einstein's Relativity. For this a comparison is made with Lorentz's Aether Theory. Two classes of possible experiments to detect violation of Special Relativity are examined with corresponding theorems proving them to lead to negative results, contrary to the statements of the proponents. Possible sources of violation of Relativity Theory are examined.

Key-words: Einstein relativity; Lorentz's theory.

1 INTRODUCTION

The purpose of the present paper(*) is to compare the status of Einstein's Special Relativity[1] (SR, for short) with that of a rival theory, Lorentz's Aether Theory(**) (LAT, for short), to be explicitly defined below, having in mind the analysis of several proposed experiments to distinguish between LAT and SR. For simplicity we restrict ourselves to experiments to be made in vacuum.

In section 2 we present a number of general considerations which clear up some of the misconceptions usually quoted in the literature having to do with LAT and SR. Our discussion makes it clear that the one-way velocity of light has no absolute meaning even in LAT. The problem of using different coordinate gauges in both theories is examined. It is shown the LAT is more restrictive than SR, thus leaving open the possibility of existence of some non-Lorentz invariant phenomena in nature, even if most of physics is Lorentz invariant.

In section 3 we examine rapidly the problem of computations using LAT or SR. Two classes of proposed experiments are shown to give the same result for LAT and SR contrary to the conclusions of the proponents. The material of section 3 is

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(*) Preliminary results of this paper were presented by one of us (J.T.) in his invited talk at the 2nd Brazilian National Conference on the Physics of Fields and Particles, in Cambuquira (1980).

(**) Erlichson[2] calls "Rod Contraction-Clock Retardation (RC-CR-theory)" the Lorentz's Aether Theory. However, although the paper presents a history of the RC-CR theory, showing that it never existed in a coherent formulation before 1905 it fails in characterizing LAT. Despite the very interesting papers published by Ives[3], the present paper seems to be the first to define LAT in a consistent way.

used to analyse certain misconceptions appearing in recently proposed experiments to distinguish LAT from SR [4]. Positive results allowing distinction of these theories, when explicit non-Lorentz invariant laws are postulated for some effects, shall be presented in a forthcoming paper [5]. No contradiction is found regarding Marinov's effect [6], which violates SR but not LAT.

In section 4, we present our conclusions, and conjectures are made regarding the origin of possible non-Lorentz invariant phenomena.

2 GENERAL CONSIDERATIONS

Modern Physics takes for granted that Lorentz invariance can be applied to all non-gravitational phenomena(*) under all possible conditions. Most text books and review articles (with a few exceptions) state with emphasis that SR is an exceptionally well-established theory. They consider SR a closed subject, there being nothing more to be seriously discussed, certainly not the existence of privileged reference frames and the aether. Serious physicists, with exceptions, do look askance to any paper where mention of breakdown of Lorentz invariance is made.

This attitude is quite unjustified. Indeed, the founda-

(*) Modern cosmology teaches us the existence of a preferred reference frame in a way that according to Dirac [7,8] departs very much from both the principles of Special and General Relativity.

tions of SR are not a matter of universal consensus[10], and have not been completely tested by experiments. Actually there is now some evidence(**) that certain experiments involving both electromagnetic radiation and the roto-translational motion of solid bodies do violate SR[5,6,9,12], although for the large majority of physical conditions SR seems to be a very good theory.

If a breakdown of Lorentz invariance occurs for some physical phenomenon, the scheme to be used must be different from the one based on SR, but must contain it for special situations. We shall use here, as an alternative, LAT which is wider than SR being based only on the following assumptions.

(i) isotropic propagation of light in vacuum with velocity $c (c = 1)$ in S_0 (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_0 (where all clocks are synchronized, say, by light signals (Einstein's method), slow transportation of clocks, rotating shafts (Marinov's method)[6], etc...) given by

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

where $\vec{v}(t)$ is the velocity of the clock as measured in S_0. For constant velocity, eq. (1) reads

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

(**) Torr et al[12] are observing small violations of SR in the proposed rotor Doppler shift experiment of Ref.(11). In Ref.(5) we show that the effect to be observed in LAT is 10^{-3} of the Torr et al's results. We also present a model which agrees quantitatively with the data of their experiment.

(iii) Lorentz-FitzGerald contraction of the length of a solid body in *translational uniform* motion with velocity $\vec{v} = v\hat{e}_x$ (v, a constant) as compared to the length at rest in S_0

$$\delta X_0 = (1 - v^2)^{-1/2}\,\delta x$$
$$\delta Y_0 = \delta y \qquad (2)$$
$$\delta Z_0 = \delta z$$

In eq.(2), $(\delta X_0, \delta Y_0, \delta Z_0)$ refer to the projections of the solid when at rest in S_0 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_0, also measured for $\delta t = 0$, for the same orientation of the body.

(i), (ii), (iii) characterize LAT with the underlying assumptions(*):

(iv) There *exists at least one* 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_0) obey

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

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

(*) For dynamical problems, the following assumption is also needed: (vi) increase of the mass of a point particle when in motion with velocity $\vec{v}$ relative to S_0, given by $M = (1-v^2)^{-1/2} M_0$, where M_0 is the mass of the particle at rest in S_0.

This procedure may be provided by Marinov's rotating shaft *if Marinov's effect*[6] *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

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

To complete the formulation of LAT we accept the following hypothesis:

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

SR imposes besides (i), (ii), (iii) also (iv-E) for an internal synchronization procedure used in S(*). Thus SR is not compatible with Marinov's results[6].

As said above, contrary to SR, alternative internal synchronizations to eq.(3) are permitted in LAT. We like to mention that besides Einstein's synchronization leading to eq.(4), this relation is also valid for synchronization with arbitrarily slow motion of physical clocks in the S frame (satisfying eq.(1))

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

even in LAT. This is an obvious consequence of an analysis made by us in previous papers[4,13] and is thus equivalent to Einstein's method(*).

Assumptions (i), (ii), (iii), (iv-E) are equivalent to the requirement in SR of invariance of all physical laws under Lorentz transformations (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 phenomenon in nature (even if most of physics seems to be Lorentz-invariant).

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

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

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

On the other hand, with postulates (i), (ii), (iii),(iv-E),

(*) We take this opportunity to correct a misprint in the abstract of the paper of Ref.(13): instead of "to order v" it must read "to any order in v, for $\omega \to 0$".

(**) These transformations used recently by Marinov[14] have been used earlier by Tangherline[15]. See also Ref.(3).

the Einstein-Lorentz transformations(*) are more natural (in SR), *but not necessary*(**), for the coordinates $(\vec{x}',t')$ in the moving frame S (we are using t', now, instead of T_E)

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

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. Conversely, as is known, eq.(4) is usually obtained from the light axiom [1]. Certainly the coordinate gauge of eq.(6), as well as ε-synchronized coordinates [17] $(0 < \varepsilon < 1)$, can be used both in SR and LAT, and can be obtained by *internal* synchronization procedures(***). However, the coordinate gauge of eq.(5), may be used also in SR, *only* using an *external* synchronization procedure by communication with the observers in S_0. Actually even arbitrary coordinate relations may be used (General Relativity with flat metric).

LAT, as is well known [2,3], predicts nothing different from SR for phenomena involving the dynamics of point particles and electromagnetic phenomena in vacuum (and eventually in material media). Indeed, Lorentz [18] stated that he proved the Princi-

(*) We are aware of the pre-history of Lorentz Transformations [16], and here we call eqs.(6) the Einsteins-Lorentz transformations to emphasize one of the important differences of LAT and SR, namely (iv-L) versus (iv-E).

(**) However as most of the physics is invariant under the group defined by eqs.(6), these transformations are canonical!

(***) ε-synchronized coordinates do not change, of course, the fundamental relation (iv-E).

ple of Relativity for these cases, while Einstein had to assume it as a postulate. Thus we need some non-Lorentz invariant phenomenon to be involved in the experiment if failures of SR are to be detected.

From the above discussion it results that the one-way velocity of light cannot have an absolute meaning even in LAT. Indeed, if we use physical rods and clocks synchronized by slow transportation, to measure the velocity of light in S, we find isotropic propagation of light in S, even in LAT, since no non-Lorentz invariant phenomena are involved. The anisotropy found when synchronization (iv-L) is used is only a coordinate effect. Coordinates are labels but not physics!

The fact that the ELG can be used in LAT by internal synchronization procedure, but the IMG cannot be used in SR by internal synchronization procedure shows again that SR is more restrictive than LAT. This possibility of using the ELG in LAT is the origin of the identification of LAT (without assumption (iv-L)) with SR as done(*) e.g. in Refs. (19,20,21,22). However this identification *is not general*. We remember that SR imposes a unique behavior for *any* physical system (and phenomenon), as a consequence of the postulate that the Poincaré-group is the invariance group of all physical systems (and phenomena) in all

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(*) We should remark, for example, that the complete identification of LAT and S.R. obtained in Ref.(22) occurs only because of the *additional* postulate used by Janossy that for *any* physical system all other possible Lorentz-deformed versions exist. However, this is only the Principle of Relativity (active Lorentz invariance) stated in other terms, thus presupposing SR.

possible conditions, whereas LAT leaves open some new possibilities. Indeed, if Lorentz invariance (which is permissible for many situations in LAT) looses its generality in some cases, being broken, then the underlying assumption (iv-L) of LAT may result as a very particular synchronization procedure in the moving frame S.

3 NULL RESULTS IN SOME EXPERIMENTS SUPPOSEDLY DESIGNED TO DETECT FAILURE OF SR.

Marinov claims that as a result of his experiments [6], a cylinder in roto-translational motion with the velocity $\vec{V}$ (relative to S_0) parallel to the angular velocity along its axis does not suffer the Lorentz-twist predicted by SR(*), thus leading to the synchronization of eq.(3), instead of eq. (4), invalidating the generality of SR, and thus favouring LAT. Remember that assumption (iii) of LAT predicts the behaviour of a solid body in *uniform translational motion only*. This do not exclude the possibility that (iii) is globally but not locally valid for the roto-translational motion. It is most unsatisfactory that Marinov's experiment has not been reproduced independently even to prove it wrong, as, to our knowledge, it is the first clear-cut contradiction of SR. Prokhovnik [17], al

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(*) The necessity of such a twist in SR seems to have been first noted by Wood [23] in 1911. The occurrence of local Lorentz-contraction for a solid in roto-translational motion implies necessarily the appearance in LAT of the Lorentz-twist, as shown later by Ives (Ref.(3), pp.58 - 64). Nevertheless it must be said that the Lorentz contraction does not seem possible to occur for all general motions of a solid body [24].

so proved that LAT implies the Lorentz twist (not found by Marinov) if the stress-shear wave in a rotating cylinder is an electromagnetic phenomenon and propagates with velocity c relative to S_0. Actually we may state with no need of computations that such violation of Lorentz invariance reported by Marinov cannot result from electromagnetic interactions only (as presently understood), as they are Lorentz invariant.

We proceed now under the following hypothesis 1(*) "Violations of Lorentz-invariance exist only for the phenomena involving roto-translational motion of solid bodies relative to S_0, and disappear in a continuous way when the angular velocity vanishes ($\omega \to 0$)".

We shall consider in what follows two classes of situations appearing in proposed experiments to detect violations of Lorentz invariance, involving roto-translational motion.

CLASS I: Situations obeying hypothesis 1 in presence of Lorentz invariant phenomena (electromagnetic radiation, point particles motion, etc.).

CLASS II: Situations involving roto-translational motion of solid bodies but with the explicit use in the computation of *uniform rotation* ($\vec{\omega}$) *in the laboratory*[4,5], without explicitly using either the hypothesis that generatrices of rotating cylinders are deformed in the laboratory (Marinov twist $\equiv$ anti-Lorentz

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(*) Of course, other kinds of violations are possible in principle, but will not be considered here. Also possibilities of non continuous transitions at $\omega = 0$ are excluded. The continuity condition is intrinsic to our definition of LAT.

twist), and/or that radii orthogonal to $\vec{\omega}$ are deformed in the laboratory and/or that circles are deformed in the laboratory(*), (or that the corresponding properties occur in the descriptions of the experiments in the S_0 frame).

Here as a preliminary step, we wish to clear the air and examine two theorems valid if LAT is true - the first holds for class I experiments and the second for class II situations. These theorems although trivial assure that exactly null results must be obtained for the *theoretical prediction*(**) of a number of proposed experiments quoted in the literature, with the claim of distinguishing results from LAT and SR.

THEOREM I: A theoretical prediction in LAT for *any* experiment of class I is identical to the corresponding prediction of SR in the limit $\omega = 0$.

Thus in this limit LAT is indistinguishable from SR. Actually Marinov's effect, being linear in ω, is allowed by this theorem.

Theorem I is an obvious direct consequence of hypothesis I.

We notice that in several papers, including Refs.(25,26) the conditions for application of Theorem I are valid. Thus, without any computation we state that the theoretical predictions of a finite observable effect *independent of* ω obtained in these papers are wrong. This was actually proved by detailed

(*) It is understood that the ELG is used in the laboratory S.

(**) Of course, the experiment *may eventually* give positive results if conditions for validity of the theorems are not physically fulfilled.

computation by Tyapkin[27] to order V, and by us[13] to all orders in V. Thus any future proposal violating Theorem I should be discarded a priori. Actually if authors and referees where conscious of this trivial result a number of papers would never appear in print.

THEOREM II: Any proposed experiment of class II leads to result in LAT identical to those of SR for arbitrary ω.

Notice that for $\omega \to 0$, constant in IMG, the equivalence with SR is assured by Theorem I. Notice also that this theorem does not apply to the calculation to Marinov's effect where Lorentz-twist in S_0 is assumed not to exist (and Marinov twist to exist in S in the ELG).

To prove Theorem II it is enough to observe that for situations of class II there can be no violation of SR according to Hypothesis I. Indeed, if it existed for $\omega \neq 0$ at least one of the possible deformations referred to in the definition of class II should exist and/or the angular velocity should vary with time in S (in ELG), as can be proved[5]. Therefore as no non-Lorentz invariant phenomenon are involved *in the computation* LAT implies SR and no effect different from SR can be obtained.

Again, without any computation we can state that the *calculations* made in a series of proposed rotor experiments with Doppler shift(*), as e.g., in Refs.(11,28,29,...) must give

(*) The null results of the experiment of Ref.(28) lead Moller[30] erroneously to state that it cannot be explained by an hypothesis of the Lorentz-FitzGerald type, thus favouring SR. For a discussion of this point see Ref.(5).

the same result, as in SR, *unless* the conditions of the theorems are surrepticiously violated in the computations. Typical errors in these papers, as well as others dealing with LAT & SR experiments are of the following kinds: (i) Neglect of the term $\vec{v}.\vec{V}$ in the expansion of $[1 + (\vec{v} + \vec{V})^2]^{1/2}$ (see Ref. (24), (ii) Use of Newtonian addition of velocities instead of the one valid in LAT for the gauge used (IMG ou ELG) (see Ref. (11); (iii) Neglecting possible ficticious or coordinate effects, like aberration (see Ref. (31) and the comments of Ref. (32)). Indeed careful computation in the mentioned papers uncovers the essential mistake whose correction leads to the SR result. Thus, the Doppler shift predicted by LAT *if the conditions of Class II are respected* is identical to the result of SR[32,33,34,35]. If Class II conditions are not respected then explicit breakdown of Lorentz invariance occurs for Doppler shift-rotor experiments as proved in Ref. (5).

Indeed, we showed[5] that in LAT there is an observable effect, which is however 10^{-3} smaller then the experimental results of Torr et al.[12] and has the wrong angular variation. Besides, our results contradict those of Ref. (11).

We also considered a model[5], not consistent with LAT and with hypothesis I, where the angular velocity of the rotor is assumed to be constant in S_0. We obtain in this way a result consistent with the observations of Ref. (12).

4 CONCLUSIONS AND COMMENTS

In this paper we reexamine the issue of the differences among the Lorentz Aether Theory and Special Relativity. It is made clear that the second, considered as a predictive formalism, is more restrictive than the first. This has been stressed before by Dirac[8] who stated that "in one sense Lorentz was correct and Einstein was wrong ... to impose that it would ever be impossible for an absolute zero in velocity to show up was going a bit too far".

It was shown that the coordinates are labels. ELG is convenient for the description of Lorentz-invariant phenomena as they are canonical coordinates keeping the form of the laws governing these phenomena in the moving frame. If we use IMG, which are non-canonical for these phenomena, new "ficticious" or coordinate effects (aberration, etc.) should be taken into account to correctly calculate the results in the moving frame.

If in some domain of Physics the laws are not Lorentz-invariant, we might prepare an internal clock synchronization procedure (involving some of these phenomena) which may lead to experiments appropriate to detect absolute motion or failure of Einstein's Special Relativity. However, this theory should remain valid when no such phenomena are involved as seems to be the case with the field theories and particle dynamics with present-day energies.

Leaving for a future paper[5] the explicit examination of such situations, we have considered two theorems which apply to the classes of proposed experiments that, contrary to statements of the authors, lead to non-observable effects which could distinguish LAT from SR.

Marinov's results, do not contradict these theorems. If they are correct, he has proved that the laws involved in the Physics of rotating solids (metals) are not Lorentz-invariant. This cannot come from electromagnetic interactions (as presently understood). Thus, we like to speculate that it should come from eventual non-Lorentz-invariant many-body interactions and/or quantum effects. (The possibility of spontaneous breakdown of Lorentz-invariance due to "boundary conditions" is examined in Refs. (9.36)).

We would like also to mention, without additional comments, a number of suggested experiments (and models) that eventually may detect a breakdown of Lorentz-invariance. They are related to the Einstein-Podolsky-Rosen[37] paradox, the recent discovery by Aspect et al[38] of space-like correlations, the colapse of the wave-function problem[39], as well as the problem of a minimum lenght[40] and time interval[41], and situations involving very high energy phenomena[42,43,44]. Finally we mention the problem associated with finite space-time lattices[44].

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