Two-Way Speed of Light and Lorentz-FitzGerald’s Contraction in Aether Theory*

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Comments: PDF, 10 pages, 5 figures
Subj-class: General Physics

This paper aims at demonstrating that: 1/ Assuming the equality of the two-way transit time of light in vacuo, along the two perpendicular arms of Michelson’s interferometers (modern versions of Michelson’s experiment), and the anisotropy of the one-way speed of light in the Earth frame, two facts supported today by strong experimental arguments, length contraction (in Lorentz and FitzGerald’s approach) should no longer be regarded as an ad hoc hypothesis, it appears necessary and can be easily deduced. 2/ It is greatly the merit of Builder and Prokhovnik to have demonstrated that, assuming length contraction, the two-way transit time of light along a rod is the same in any direction of space. We agree with these authors up to this point, but, contrary to what is often believed, their approach failed to reconcile aether theory with the invariance of the apparent (measured) two-way speed of light. Yet, as we shall show, due to the systematic measurement distortions entailed by length contraction and clock retardation assumed by aether theory, the two-way speed of light, although anisotropic and dependent on the absolute speed of the frame where it is measured, is always found equal to C. The reasons of this paradoxical but important result will be developed here. They confirm Lorentz-Fitzgerald’s contraction and lend support of the existence of a preferred aether frame.

I. Introduction.

Since the early days of relativity theory, Lorentz-FitzGerald’s contraction has been the focus of a debate which is still lively today, and divides physicists in opposite camps.

Some reegard length contraction (L.C) as a naïve opinion, for example Wesley 1, Phipps 2, Cornille 3, Galeczki 4. Some others consider it as a fundamental process which explains a lot of experimental facts. Among them Bell 5, Selleri 6, Builder, Prokhovnik 7, Dishington 8, Mansouri and Sexl 9, Wilhelm 10a.

Length contraction has been proposed by Lorentz 11 and FitzGerald 12 in order to explain the null result of Michelson’s experiment. (In fact the result was not completely null, but much smaller than the result expected. We know today that a completely null result can only be observed in vacuum experiments)

It is worth noting that the conception shared by Lorentz and FitzGerald and by the above mentioned authors about L.C is completely different from the L.C of special relativity. It is the same for all observers. It is not observer dependent. Nevertheless, since the standard used to measure the length of a moving body is contracted in the same ratio as the body itself, the contraction cannot be demonstrated by an observer attached to the moving frame. Therefore, L.C was never directly observed and only an indirect measurement could be envisaged. This was the objective of different renowned physicists who tried to observe the physical modifications entailed by motion: variation of the refractive index of a refringent solid (Rayleigh 13 and Brace 14), influence of the aether wind on a

* The present article is an updated version of an essay published in the late papers p 175 of the International meeting Physical Interpretations of Relativity Theory VII (PIRT), held at the Imperial College, University of London, (15-18 September 2000).
charged condenser the plates of which make a certain angle with the direction of translation (Trouton and Noble 15), experiments of Trouton and Rankine 16 and of Chase 17 and Tomashek 18 on the electrical resistance of moving objects, and finally of Wood Tomlison and Essex 19 on the frequency of the longitudinal vibration of a rod.

Yet the experiments all proved negative.

In order to justify the lack of experimental evidence, Lorentz was compelled to postulate the variation of mass with speed (see ref 20, p 99 and 105). But, in ref 21, we demonstrated that if we assume the existence of a privileged aether frame, the space-time transformations derived from the Lorentz postulates, are reducible to the Galilean transformations after correction of the systematic measurement distortions due to length contraction, clock retardation and arbitrary clock synchronization (i.e Einstein-Poincaré procedure or slow clock transport). Therefore, at first sight, these transformations do not seem compatible with the law of variation of mass with speed. (Indeed in order to demonstrate this law, we generally make use of Einstein’s relativity principle which supposes the conservation of the total relativistic momentum in any inertial frame, and does not assume the Galilean transformations).

Thus, the other Lorentz assumptions seemed incompatible with one of them $m = m_0 \gamma$ which is an important experimental law. For this reason they appeared questionable to us in some earlier publications (ref 22,23).

Yet, since that time, we have become aware that if we assume the existence of a preferred aether frame and of the aether drift associated with it, real frames are never perfectly inertial and therefore not equivalent for the description of the physical laws (see ref 24). As a result, the objections opposed to Lorentz’s justification can be overcome24. In fact in aether theory, the formula $m = m_0 \gamma$ has not exactly the same meaning as in relativity: $m_0$ is not the rest mass in any inertial frame, it is the rest mass in the aether frame25.

Note that another argument seemed, at first sight, to go against Lorentz-Fitzgerald’s contraction: the compressibility of matter is limited, and length contraction seems difficult to justify at very high speeds. For example at 0.9999C the ratio $L/L_0$ would be reduced to 1.4%.

But we can answer that the law has been proposed following an experiment performed at low speed (Michelson’s experiment). It would not exactly adopt the same form at very high speeds.

Today we have come to realize that strong arguments exist in support of Lorentz-Fitzgerald’s contraction (L.C). One of these arguments is that L.C enables to explain (in all directions of space and not only in two perpendicular directions) the isotropy of the apparent two way speed of light. L C sets up the aether assumption on solid bases which enables it to be confronted with special relativity.

II.     Lorentz-FitzGerald’s contraction explains the null result observed in vacuum Michelson’s experiments.

We know today that, even if we use two clocks to make the measurement, the usual synchronization procedures (Einstein-Poincaré procedure or slow clock transport) only enable measurement of the two way speed of light 7,26. As we shall show, the aether theory maintains that the value $C$ is found when the two-way speed of light is measured with contracted meter sticks and clocks slowed down by motion.

According to Anderson, Vetharaniam and Stedman 27, all the recent experiments purporting to illuminate the isotropy of the one way speed of light were based on erroneous ideas (because they considered that the slow clock transport procedure allows exact synchronization).

On the contrary, a number of arguments are put forward today in favour of the anisotropy of the one-way speed of light, when no distortion alter the measurement. Although its direct estimate comes up against major difficulties, several authors applied themselves to evaluate it from the measurement of the terrestrial aether velocity, based on the fact that light signals propagate isotropically in the aether frame. (Note that the orbital velocity of the Earth is of the order of 30Km/sec. Therefore, as a first approximation the absolute speed of the Earth can be identified with the solar System absolute velocity which, as we will see, is estimated at about 370 Km/sec)
A first evaluation of the solar system absolute velocity was already made in 1968 by De Vaucouleurs and Peters, who measured the anisotropy of the red shift relative to many distant galaxies. The experiment was made again by Rubin in 1976.

A more reliable estimate was obtained by measuring the anisotropy of the 2.7° K microwave background radiation, uniformly distributed throughout the Universe. "An observer moving with velocity v relative to the microwave background can detect a larger microwave flux in the forward direction (+v) and a smaller microwave flux in the rearward direction (-v). He can observe a violet shift in the forward direction (+v) and a red shift in the rearward direction (-v) (Wilhelm)."

From this data, the absolute velocity of the solar system could be measured ((Conklin (1969), Henry (1971), Smoot et al (1977), Gorenstein and Smoot (1981), Partridge (1988)). Let us also quote the method of measurement based on the determination of the muon flux anisotropy (Monstein and Wesley (1996)). An assessment of all these experiments is given by Wilhelm 10a and Wesley 10b.

Another verification of the absolute speed of the Earth frame was made by Roland De Witte in 1991. To this end, 5 Mhz radio frequency signals were sent in two opposite directions through two buried co-axial cables linking two caesium beam clocks separated by 1.5 km. Changes in propagation times were observed and were recorded over 178 days. De Witte interpreted the results as evidence of absolute motion. (Unpublished, cited by Cahill).

More recently (april 2003), Cahill and Kitto reinterpreted the Michelson and Morley experiment. They asserted that Michelson interferometers operating in gas mode are capable of revealing absolute motion 28. They analysed the old results from gas-mode Michelson interferometers experiments which always showed small but significant effects. The authors asserted that after correcting for the air, the Miller experiment gives an absolute speed of the Earth frame of v=335 ± 57 Km/sec.

Marinov 29 also attested having measured the absolute velocity of the solar system by means of different devices (coupled mirrors experiment, toothed wheels experiment). The experiments are described in detail in the book of Wesley 1, and are quoted by Wilhelm 10a.

According to Wesley 10b,30 the Marinov (1974, 1977a, 1980b) coupled mirrors experiment is one of the most brilliant and ingenious experiment of all time. It measures the very small quantity v/C where v is the absolute velocity of the observer by using very clever stratagems. The coupled mirrors experiment enabled the author to assert that the absolute velocity of the solar system is of the order of 320 ± 20 Km/sec.

This result was in agreement with most of the observations and experiments described above which lend support to the existence of a fundamental inertial frame, whose absolute speed is zero, but whose relative speed with respect to the Earth frame is of the order of 350 km/sec.

Consider now a Michelson interferometer whose longitudinal arm is aligned along the x0-axis of a coordinate system S0 (0, x0, y0, z0) attached to the Cosmic Substratum. The device is at rest in the Earth frame which for our purpose is assumed to move along the x0-axis at speed v during the time of the experiment.

It is easy to verify that, in reply to the statement that the speed of light is C - v in the + x0 direction, and C + v in the opposite direction, the arm will be contracted in the ratio:

$$\ell = \ell_0 \sqrt{1 - \frac{v^2}{C^2}}$$

where is the length of the arm in motion, and \(\ell_0\) its length when it is at rest in the aether frame.

With the same starting point, we shall show that the apparent (measured) two-way speed of light along the x0-axis, is equal to C independently of the speed v.

Let us demonstrate formula (1).

A priori, we do not know if \(\ell = \ell_0\) or not. The two-way transit time of light along the longitudinal arm will be:

$$t_1 = \frac{\ell}{C - v} + \frac{\ell}{C + v} = \frac{2\ell}{C(1 - \frac{v^2}{C^2})}$$

Now, in the arm perpendicular to the direction of motion, there is no length contraction.

The speed of light is C exclusively in the aether frame. The signal starts from a point P in this frame towards a point Q at the extremity of the arm and then comes back towards point P'. During that time, the interferometer has covered the path vt2 (see figure1).
we have
\[ \left( \frac{Ct_2}{2} \right)^2 - \left( \frac{v_1}{2} \right)^2 = l_0^2 \]
\[ \Rightarrow \quad l_0 = \frac{t_2}{2} \sqrt{C^2 - v^2} \]
so that
\[ t_2 = \frac{2l_0}{C\sqrt{1-v^2/C^2}} \] (3)

In vacuum experiments the displacement of the fringes when we change the orientation of the interferometer is hardly perceptible. Neglecting this fringe shift* which is really too small to explain the existence of an aether drift of the order of 300 km/sec, we can write \( t_1 = t_2 \), that is:
\[ 2\ell = \frac{2l_0}{C\sqrt{1-v^2/C^2}} \]
Hence
\[ \ell = \frac{l_0}{C\sqrt{1-v^2/C^2}} \]

Therefore, if we take the anisotropy of the one way speed of light into account, length contraction must no longer be considered as an ad hoc hypothesis. On the contrary, it must be seen as a necessary cause of the Michelson result.

Now, on account of clock retardation, the apparent (measured) two-way transit time of light will be (from (3)):
\[ \frac{2\ell}{C} \]

In aether theory, length contraction is a real process valid for all observers. It is not observer dependent. Since the length of the longitudinal arm is determined with a standard contracted in the same ratio as the arm, it is found equal to \( l_0 \) and not to \( \ell \), so that the apparent (measured) two way speed of light along the \( x_0 \)-axis will be found equal to \( C \). (It is in fact different from its real value, which according to formula (2) is \( C\sqrt{1-v^2/C^2} \).

NB - In the absence of length contraction, the apparent two-way speed of light would not have been found equal to \( C \), in contradiction with the experiment.

* Note that, the modern versions of Michelson’s experiment in vacuo greatly confirm the equality of the two-way transit time of light along the two arms of the interferometer. The measurements made by Joos (1930), Jaseja et al (1964), Brillet and Hall have verified this result which was almost perfect for Brillet and Hall. For a review of the topic consult H.C Hayden, Phys essays 4, 36, (1991).
III. Lorentz-FitzGerald’s contraction explains the *apparent* speed of light invariance.

- But this is not all. We will now demonstrate that L.C explains the independence of the *apparent* two way speed of light from any direction of space and from the speed $v$.

The demonstration is based on Builder and Prokhovnik’s studies whose importance is indisputable but, as we will see, some of the conclusions of Prokhovnik were questionable and could not enable us to demonstrate that this *apparent* velocity is $C$ in any direction of space.

Consider the two frames $S_0$ and $S$ discussed in the previous paragraph, and suppose that a rod $AB$ making an angle $\theta$ with the $x_0$ x-axis, is at rest with respect to frame $S$ (see figure 2).

![Figure 2](image)

The rod $AB$ is at rest with respect to frame $S$

At the two ends of the rod, let us place two mirrors facing one another by their reflecting surface, which is perpendicular to the axis of the rod $\ell = AB$. At the initial instant, the two frames $S_0$ and $S$ are coincident. At this very instant a light signal starts from the common origin and travels along the rod towards point $B$. After reflection the signal returns to point $A$.

We do not suppose a priori that $\ell = l_0$ (where $l_0$ is the length of the rod when it is at rest in the aether frame $S_0$). We remark that the path of the light signal along the rod is related to the speed $C_1$ by the relation:

$$t = \frac{AB}{C_1}$$

(see figure 3)

where $t$ is the time needed by the signal to cover the distance $AB$.

In addition, when the signal reaches point $B$, frame $S$ has moved away from frame $S_0$ a distance:

$$AA' = vt$$

So that:

$$v = \frac{AA'}{t}$$

Now, from the point of view of an observer at rest in frame $S_0$, the signal goes from point $A$ to point $B'$ (see figure 3).

![Figure 3](image)

The speed of light is equal to $C$ from $A$ to $B'$, and to $C_1$ from $A'$ to $B'$.

$C$ being the speed of light in frame $S_0$, we have:

$$\frac{AB'}{t} = C$$

and hence, the projection along the x-axis of the speed of light $C_1$ relative to frame $S$, will be equal to $C \cos \alpha - v$. 

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We remark that: \[ C \cos \alpha - v = C_1 \cos \theta \]

The three speeds, \( C, C_1 \) and \( v \) being proportional to the three lengths \( AB', AB \) and \( AA' \) with the same coefficient of proportionality, we have

\[ C^2 = (C_1 \cos \theta + v)^2 + C_1^2 \sin^2 \theta \]

Therefore:

\[ C_1^2 + 2v C_1 \cos \theta - (C^2 - v^2) = 0 \]  \[ (4) \]

(We must emphasize that equation (4) implies that the three speeds \( C, C_1 \) and \( v \) have been measured with the help of the same clocks, which obviously are clocks not slowed down by motion).

Resolving the second degree equation, we obtain:

\[ C_1 = -v \cos \theta \pm \sqrt{C^2 - v^2 \sin^2 \theta} \]

The condition \( C_1 = C \) when \( v = 0 \) compels us to only retain the + sign so:

\[ C_1 = -v \cos \theta + \sqrt{C^2 - v^2 \sin^2 \theta} \]

- Now, the return of light can be illustrated by the figure 4 below:

![Figure 4](image)

The speed of light is equal to \( C \) from \( B' \) to \( A'' \) and to \( C_2 \) from \( B'' \) to \( A' \).

From the point of view of an observer attached to frame \( S \), the light comes back to its initial position with the speed \( C_2 \).

So we can write:

\[ C_2 = \frac{B'A'}{t'} \]

For the observer attached to frame \( S_0 \) the light comes from \( B' \) to \( A'' \) with the speed \( C \), so that

\[ C = \frac{B'A''}{t'} \]

During the light transfer, frame \( S \) has moved from \( A' \) to \( A'' \) with the speed \( v \) therefore:

\[ v = \frac{A'A''}{t'} \]

The projection of the speed of light relative to frame \( S \) along the x-axis will be

\[ C_2 \cos \theta = C \cos \alpha' + v \]

we easily verify that:

\[ (C_2 \cos \theta - v)^2 + (C_2 \sin \theta)^2 = C^2 \]

therefore

\[ C_2 = v \cos \theta + \sqrt{C^2 - v^2 \sin^2 \theta} \]

The two-way transit time of light along the rod \( AB \), measured with clocks not slowed down by motion, is:

\[ 2T = \frac{\ell}{C_1} + \frac{\ell}{C_2} \]  \[ (5) \]

According to the experiment, \( T \) must be essentially independent of the angle \( \theta \). Therefore, \( 2T \) must be equal to:

\[ \frac{2\ell_0}{C \sqrt{1 - v^2/C^2}} \]

which is the two way transit time of light along the y direction (previously calculated).
We can see that, in order for this condition to be satisfied, the projection of the rod along the x-axis must shrink in such a way that:

\[ \ell \cos \theta = \ell_0 \cos \varphi \sqrt{1-v^2/C^2} \quad \text{(see figure 5)} \]

where \( \varphi \) was the angle separating the rod and the \( x_0 \)-axis when the rod was at rest in frame \( S_0 \).

![Figure 5](image)

Along the \( x_0, x \)-axis, the projection of the rod \( \ell_0 \) contracts, along the y-axis it is not modified.

from:

\[ \ell_0 \cos \varphi = \frac{\ell \cos \theta}{\sqrt{1-v^2/C^2}} \]

and

\[ \ell_0 \sin \varphi = \ell \sin \theta \]

we easily verify that:

\[ \left( \frac{\ell \cos \theta}{\sqrt{1-v^2/C^2}} \right)^2 + \left( \ell \sin \theta \right)^2 = \ell_0^2 \]

finally:

\[ \ell = \frac{\ell_0 \left(1-v^2/C^2 \right)^{1/2}}{\left(1-v^2 \sin^2 \theta/C^2 \right)^{1/2}} \]

Replacing \( \ell \) with this expression in (5) we obtain, as expected:

\[ 2T = \frac{2\ell_0}{C\sqrt{1-v^2/C^2}} \quad \text{(6)} \]

We conclude that length contraction along the \( x_0, x \)-axis is a necessary condition so that the two-way transit time of light along a rod is independent of the orientation of the rod.

- But this is not all. The same conditions combined with clock retardation, enable us to demonstrate that the apparent (measured) two-way speed of light is \( C \) in any direction of space.

Clock retardation is an experimental fact. Let us designate the apparent two-way transit time of light along the rod in frame \( S \) as \( 2 \varepsilon \). We will have (from (6)):

\[ \varepsilon = T \sqrt{1-v^2/C^2} = \frac{\ell_0}{C} \]

Now, the length of the rod, measured with a contracted meter stick, is always found equal to \( \ell_0 \), so that the two-way speed of light is (erroneously) found to be \( C \) in any direction of space and independently of the speed \( v \). (As we have seen this is also the case for the apparent one-way speed of light measured with the help of clocks synchronized by means of the Einstein-Poincaré synchronization procedure or by slow clock transport). This result is highly meaningful and is a direct consequence of the facts deduced from the Michelson and Morley experiment and the experiments and astronomical observations lending support to the anisotropy of the one-way speed of light.

**Note**

In our demonstration, although we are indebted to Prokhovnik, we differ with his conclusions; indeed, since \( C = AB/t \) and \( C = B'A''/t' \), it is obvious that \( t \) and \( t' \) are the real transit times of light along the rod (measured with clocks attached to the aether frame).
Now, since \( C_1 = \frac{AB}{t} \) and \( C_2 = \frac{B'A'}{t'} \) there is no doubt that \( C_1 \) and \( C_2 \) are also measured with the help of clocks not slowed down by motion. This is also the case for \( 2T = \frac{t}{C_1} + \frac{t'}{C_2} \).

Nevertheless, in his book "The logic of special relativity" chapter "The logic of absolute motion", Prokhovnik identifies the time \( 2T = \frac{2\ell_0}{C\sqrt{1-v^2/C^2}} \) with the two way transit time of light along the rod, measured with clocks attached to the moving frame, (see formula 5.2.4 of ref 22-1, French edition).

This cannot be true for the reason indicated above.

(Note that in our notation the moving frame is designated as S, while in Prokhovnik’s notation, S designates the aether frame and A the moving frame. We will continue the demonstration with our own notation).

In addition, if Prokhovnik’s approach were true, the apparent two-way speed of light in frame \( S \) would not be \( C \). Indeed, since the standard used for the measurement is also contracted, observer \( S \) would find \( \ell_0 \) for the length of the rod.

Therefore, the apparent (measured) two way speed of light in frame S would have been:

\[
\frac{2\ell_0}{2\ell_0/C\sqrt{1-v^2/C^2}} = C\sqrt{1-v^2/C^2}
\]

which is not in agreement with the experimental facts.

The two-way transit time of light along the moving rod, measured with clocks not slowed by motion is in fact \( 2\ell_0/C\sqrt{1-v^2/C^2} \), and the apparent two-way transit time, measured with clocks attached to frame \( S \), is \( 2\ell_0/C \). This corresponds to the experimental facts, since, with these values, the apparent two-way speed of light in frame \( S \) is found equal to

\[
\frac{2\ell_0}{2\ell_0/C} = C
\]

Note also that according to aether theory, the real two-way speed of light along the \( x_0 \), x-axis (measured with not contracted standards and with clocks not slowed down by motion) is

\[
\frac{2\ell_0\sqrt{1-v^2/C^2}}{2\ell_0/C\sqrt{1-v^2/C^2}} = C(1-v^2/C^2)
\]

Which, as expected, tends to 0 when \( v \Rightarrow C \)

Note

The hypothesis of the aether dragged by the Earth has been generally rejected because it seemed in contradiction with the theory of aberration. But, as demonstrated by Beckmann 31, Mitsopoulos 32 and Makarov 33, this is not the case.

But the theory of the dragged aether is contradicted by the experiment of Lodge 34, who demonstrated that the speed of light is not modified in the neighbourhood of a rotating wheel and by all the experiments lending support to the anisotropy of the one way speed of

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