Relativistic Interpretation (with Non-Zero Photon Mass) of the Small Ether Drift Velocity Detected by Michelson, Morley and Miller

J.P. Vigier
Université Paris VI - CNRS,. URA 769
Gravitation et Cosmologie Relativistes
Tour 22-12, Boîte 142, 4 Place Jussieu, 75005 Paris

A detailed analysis of the Michelson-Morley ether drift experiment (from 1887 to 1926) contradicts the classical law of addition of velocities. The small ether drifts first observed by Michelson are not compatible with Newtonian Mechanics. This result paved the way for the first form of the Theory of Relativity in which light velocity is always equal to c in all directions, and no such drift is possible. It is shown in this letter that the introduction of a small photon mass $m_\gamma \sim 10^{-65}$ *gr. by Einstein, Schrödinger, de Broglie et al. [1] implies a small anisotropy in the velocity of light (at each frequency) and the reintroduction of an observable absolute inertial frame. Consequently, in conjunction with Dirac s chaotic covariant ether distribution [2], this provides a relativistic interpretation of Michelson s 8.1 km s* ^{1} *absolute earth ether drift observation [3], later confirmed by Miller in 1933 [4]. More recent results are briefly discussed.*

Introduction

As is now taught in most physics textbooks, the Galilean-Newtonian law of composition of velocities (*i.e.* $\mathbf{v}_s = \mathbf{v} + \mathbf{v}_o$, where $\mathbf{v}_s$ denotes the observed velocity in inertial frame S of a particle with velocity $\mathbf{v}_o$ in an inertial frame S_o, itself moving with velocity **v** with respect to S_o) was disproved by the famous Michelson-Morley experiments of 1887 [5], thus confirming an earlier measurement of 1881. To account for this surprising result, in 1891 and 1895 Fitzgerald [6] and Lorentz [7] introduced a model of velocity dependent rod contraction and time dilation which predicted a fixed fringe system in all Michelson-type interference experiments moving at all possible velocities in all directions. As a consequence, no ether drift should appear in this type of observations. This was the starting point of Relativity Theory.

What the text books do not say, however, is that, although the Newtonian ether drift prediction did not have the anticipated magnitude (*i.e.* ~320 km s ^{1} in the apex of the observer s absolute motion), *the observed effect was not zero in Michelson s famous experiment* [3], as later confirmed by a (presently almost forgotten) set of very detailed and very careful experiments by Morley and Miller [5,4].

The aim of the present letter is to claim that since these experiments (which can be redone with modern techniques) yielded an observed significant maximum ether drift velocity (*i.e.* 8.8 km s ^{1} for the noon observations and 8.0 km s ^{1} for the evening observations in July 1887), a figure later confirmed with different types of interferometers over a full year s period by Morley and Miller [4]. This result can be interpreted within the framework of Relativity Theory using Einstein s law of velocities combined with the introduction of a small photon rest mass $m_g \sim 10^{-65}$ gr.

Ether Drift and Photon Mass

In the Special Theory of Relativity the introduction of a photon rest mass $m_\gamma \sim 10^{-65}$ gr. implies the following:

a) Energy carried by light (*i.e.* by photons) propagating with an observed frequency ν in an inertial frame S is related to a specific velocity c by the Einstein-de Broglie relation

$$E = h\nu = m_\gamma c^2 \left(1 - \frac{c_\mu^2}{c^2}\right)^{-1/2} \qquad (1)$$

a relation which suggests [1] that photons are real extended particles, moving in space and time, comparable to internal clocks beating in phase with their surrounding Maxwellian piloting waves. In this model light contains waves and particles simultaneously [1]. It is described by a complex four-vector potential A_μ with $\partial^\mu A_\mu = \partial^M A''_\mu = 0$.

b) Maxwell s equations must be completed by mass terms and represent spin 1 fields ($J = 1 \pm J_3 \pm 1,0$), where the longitudinal waves ($J_3 = 0$), which behave like Yukawa-Coulomb fields, are practically decoupled from the usual transverse ($J_3 \pm 1$) Maxwellian waves [1].

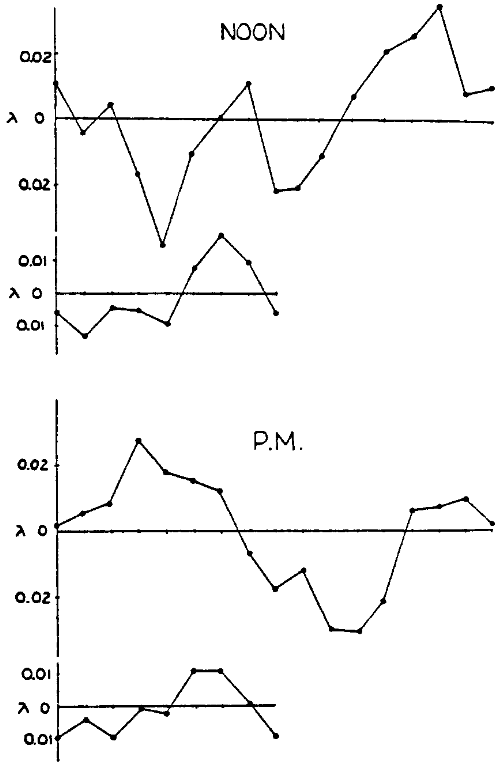

Figure 1. Fringe displacements of the original Michelson-Morley experiments of 1887.

c) Photons (in the causal stochastic interpretation) are non-dispersive particle-like packets, possibly associated with extended non-linear wave equations, which beat in phase with (*i.e.* are piloted by) their surrounding Maxwellian waves. Michelson s interference fringes are built up from superposed individual photon impacts.

d) All photon motions should be analysed within the framework of Special Relativity, *i.e.* all photons moving with local instantaneous velocity c_μ defined by the local 2.7 K microwave Planck distribution in an inertial frame S, move in the (local) absolute inertial frame S_o with the same absolute velocity c_ν^o in all directions, *i.e.*

$$c_\mu = c\cdot\left(1-\frac{m_\gamma^2 c^4}{h^2 \nu^2}\right)^{1/2}$$

e) The existence of relation (1) implies that photons of frequency μ moving in opposite directions ($\pm$) with equal velocities c_μ^o along an axis O_z in an absolute inertial frame S_o move with different c_μ^* velocities in another inertial frame S defined by a velocity v with respect to S_o. Instead of Galileo s addition law

$$c_\nu^* = c_\nu^o \pm v \qquad (2)$$

we have $\left(c_\nu^o \pm c_\nu^*\right)\to 0$ and $\left(c_\nu^{o\pm} - v\right)\to 0$ when $c_\nu^o \to c$ with increasing frequency. Einstein s law yields the relation

$$c_\nu^* = \left(c_\nu^o \pm v\right)\cdot\left(1\pm\left[c_\nu^o\cdot v\right]c^{-2}\right)^{-2}. \qquad (3)$$

This can be approximated if $v << c$ by

$$c_\nu^* \cong c_\nu^o + \left\{+c_\nu^o\cdot\left[\frac{\left(c_\nu^o\cdot v\right)}{c^2}\right]\pm v\left[1\mp\frac{\left(c_\nu^o\cdot v\right)}{c^2}\right]\right\} \qquad (4)$$

i.e. $c_\nu^* = c_\nu^o \pm \varepsilon_\gamma$, where ε_γ denotes the { } terms of relation (4), and $\varepsilon_\gamma \to 0$ when $c_\nu^o \to c$.

Comparison of (1) and (4) shows that as a consequence of Relativity Theory (when $m_\gamma \neq 0$) the absolute velocities observed in many Michelson type interference experiments are always much smaller than the real classically expected velocities by factors ranging from $1/50$ to $1/100$ when c_μ is close to c, *i.e.* $\bar{\varepsilon} << \mathbf{v}$. The introduction of a non-zero photon rest mass $m_\gamma \neq 0 = 10^{-65}$ gm thus allows a relativistic interpretation of the small ether drifts observed in many experiments, as will now be shown. These ether drift experiments, generally dismissed (without proof) as experimental artefacts, should, on the contrary, be tested with improved technology, since their confirmation would strengthen the Einstein-de Broglie idea that light is a real non-zero mass spin 1 field [1]. In fact, such experiments might be utilised to measure m_γ with the help of Sagnac-type interferometers, as will be discussed in a subsequent paper.

Michelson s and Morley s First Ether Drift Observations

If we accept the existence of an absolute inertial frame S_o, we can, in principle (as first suggested by Maxwell himself, see Appendix I), detect very small ether drifts with the help of careful interference experiments. This attempt was made in a long set of remarkable experiments by Michelson, Morley and Miller (from 1881 to 1925), which we shall now briefly recall, as they are now completely ignored in the physics community. We have purposely reproduced large excerpts from Miller s detailed review article [4] in order to convince readers that a small ether drift has effectively and consistently been observed throughout a long series of precise experiments performed by Michelson and his followers. Unless new experiments disprove these results, we should try to understand them within the framework of Relativity itself.

Michelson s experiment of 1881 in Cleveland utilized an interferometer built by Alexander Graham Bell. It was devised to observe the velocity of the earth on its orbit (v ~30 km s $^{-1}$) corresponding to an expected fringe displacement of 0.04 of the fringe width. The displacement actually observed varied only between 0.004 and 0.015 of a fringe width.

Michelson s experiment (with a much improved apparatus floating on mercury) was then performed during three days (July 8, 9 and 11, 1887) during one hour at noon and one hour in the evening also in order to detect the preconceived effect of the orbital motion of the earth towards a known point in space. No general series of observations were made. Here is Miller s account:

> *The brief series of observations was sufficient to show clearly that the effect did not have the anticipated magnitude. Moreover, and this fact must be emphasized,* ***the indicated effect was not zero****; the sensitivity of the apparatus was such that the conclusion, published in 1887, stated that the observed relative motion of the earth and ether did not exceed one-fourth of the earth s orbital velocity. This is quite different from a null effect, now so frequently imputed to this experiment by writers on Relativity*
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> *In the original account of their experiment, Michelson and Morley give the actual readings for the position of the interference fringes in the six sets of observations. The upper one of the two long curves in Fig. 1 shows the average of the three sets of readings taken at noon, and the lower long curve is the average of the three sets taken in the evening. These curves show the fringe displacements for a full turn of the interferometer, while the ether drift effect being sought is periodic in each half turn. To find the latter effect, the second half of the long curve is superimposed on the first half by addition, which cancels the full-period effect and all odd harmonics, giving the shorter curve, which is the desired half-period effect (together with any higher even harmonics which may be present). Inspection shows clearly that these curves are not of zero value, nor are the observed points scattered at random; there is a positive, systematic effect. These full-period curves have been analyzed by the mechanical harmonic analyzer, which determines the true value of the half-period effect. This, being converted into its corresponding value for the velocity of relative motion of the earth and ether, gives a velocity of 8.8 kilometers per second for the noon observations, and 8.0 kilometers per second for the evening observations. In Figure 2, the smooth curve shows the value of the ether-drift throughout the day for the latitude of Cleveland, as determined by the specifications of the drift which are derived later in this report from the observations made at Mount Wilson. The two circles on this chart show the magnitude of drift actually obtained by Michelson and Morley for the noon and evening observations, indicating a result wholly consistent with the later work at Mount Wilson.*

The ether-drift observations made by Miller prior to 1925 consisted of 1) twenty-five sets of 995 turns made in collaboration with Professor Morley in 1902-1905, 2) eighty-six sets of 1146 turns made in Cleveland in 1922-1924, and 3) one hundred and sixty-five sets of 1181 turns made at Mount Wilson in 1921 and 1924. Miller continues:

Table I. Velocities and Displacements

Epoch	Velocity (km s 1)	λ = 5700A
Feb. 8	9.3	0.104
Apr. 1	10.1	0.123
Aug. 1	11.2	0.152
Sep. 15	9.6	0.110

> *These experiments had given conclusive evidence of a real effect which was systematic but which was small in magnitude and was inexplicable as to its azimuth. A program was adopted involving an extensive series of observations for the solution of the general problem of ether-drift without any presumed effects. In order to justify general conclusions, it is necessary to have observations extending throughout the twenty-four hours of the day to show the effects of the rotation of the earth on its axis, and at several different times of the year to show the effects of the earth s orbital motion. Since the orbital motion is always tangent to the orbit, it will have different directions in different seasons, producing a resultant absolute motion peculiar to each epoch. Such observations were made at Mount Wilson for four epochs, April 1, August 1 and September 15, 1925, and February 8, 1926; the number of sets of observations for these epochs is thirty-six, ninety-six, eighty-three and one hundred and one, respectively, giving a total of 6402 turns. More than half of these readings were made in the Mount Wilson observations of 1925 and 1926. The latter observations lead to 12,800 single measures of the velocity of the ether-drift and to 25,600 single determinations of the apex of this motion.*

The results are summarized here in Figure 3. Then Miller notes:

> *The curves of observation, Fig. 3, give directly the values of the maximum velocity of relative motion of the earth and ether, as observed in the plane of the interferometer, for the four epochs; these velocities are given in Table I. The table also shows the displacements of the interference fringes, in terms of fringewidth, which would be produced in the interferometer used in these experiments, by the observed velocities of ether drift.*
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> *The three tables contain all of the data provided by the three hundred and sixteen sets of observations made at Mount Wilson in 1925 and 1926, for the solution of the ether drift problem.*

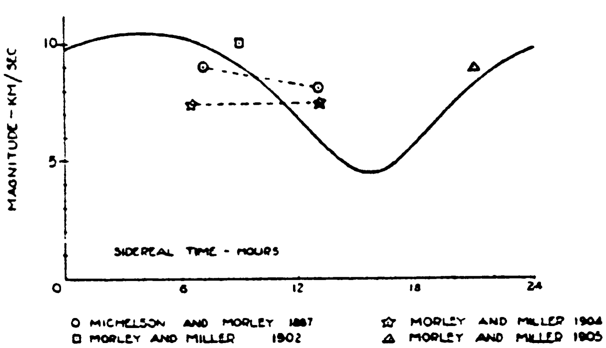

Figure 2. Velocity of ether drift, observed by Michelson and Morley in 1887, and by Morley and Miller in 1902, 1904 and 1905, compared with the velocity obtained by Miller in 1925.

In this work the calculations proceed directly from the actual observations, without any pre-assumptions as to the result. All of the original observations have been included in the calculation, without any omissions and without the assignment of weights. No corrections of any kind have been applied to the observed quantities. This procedure has been adopted as the only safe one in the first search for a hitherto unidentified effect. The present results strikingly illustrate the correctness of this method, as it now appears that the forty-six years of delay in finding the effect of the orbital motions of the earth in the ether-drift observations have been due to efforts to verify certain predictions of the so-called classical theories and to the influence of traditional points of view. [4]

A study of the numerical results as plotted in Figure 3 shows that the probable error of the observed velocity has a magnitude of ± 0.33 kilometers per second, while the

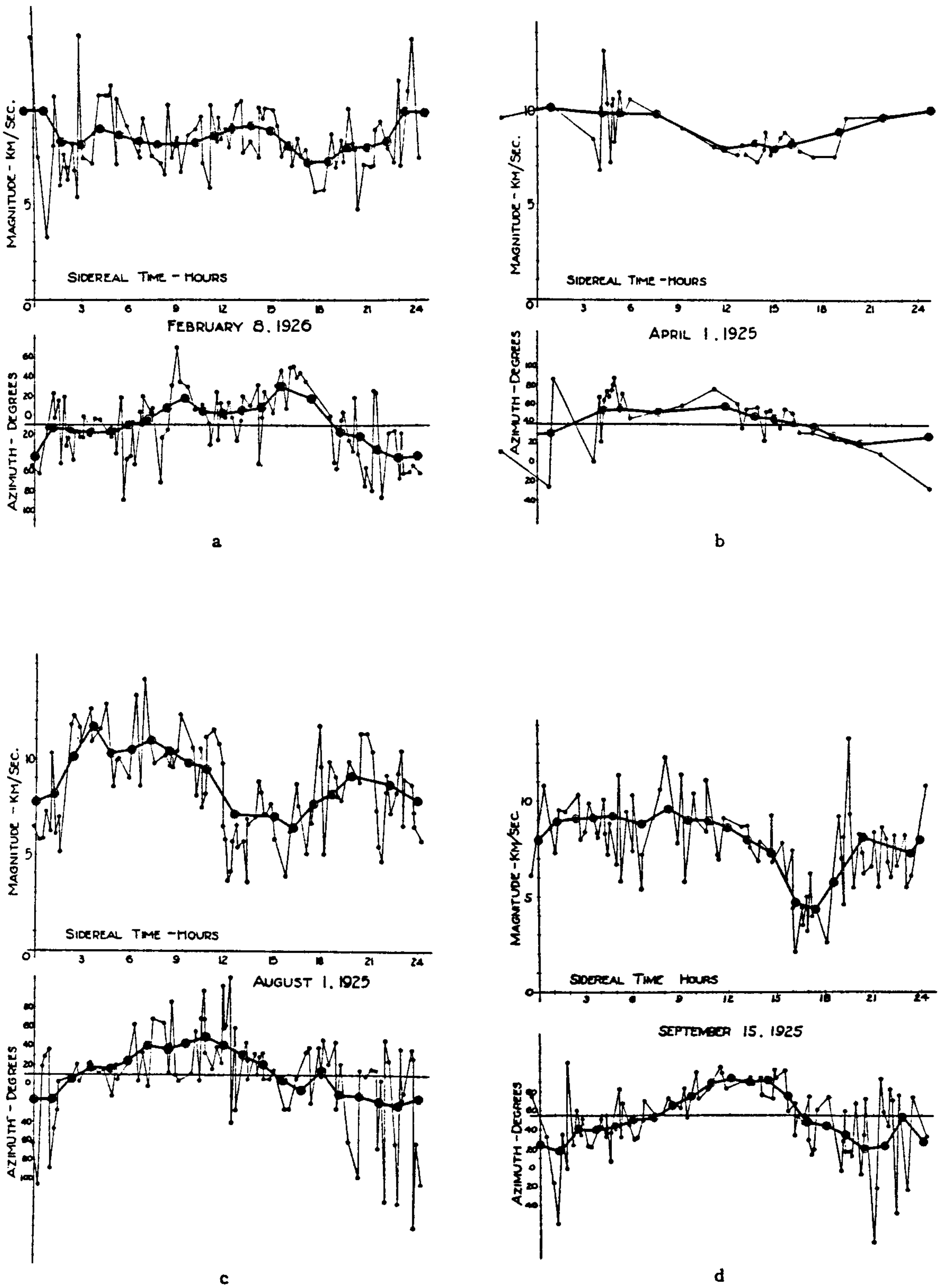

Figure 3. Single observations and average curves for the ether-drift effect at Mount Wilson in 1925-1926.

possible error in the determination of the azimuth is ± 2.5°. The probable error in right ascensions and declinations is ± 0.5°.

The absence of an absolute ether drift in some Michelson type interference experiments can be explained by the simple fact that 1) *when one measures* $\delta\lambda/\lambda$ *the average values over a whole day is always zero due to the earth s rotation,* i.e. *the plotted values follow a sinusoidal curve*; 2) their values within a few hours (or minutes) vary with the chosen time interval for the same reason since the axis of the telescope takes different orientations; 3) In all such experiments (to the best of the author s knowledge) the maximum and minimum of $\delta\lambda/\lambda$ occurs at the same sidereal time (~3-4 hours and 14-15 hours) and cancel around 9 hours and 21 hours.

An essential common point in all these experiments is that, when made over a sidereal day, all Michelson type experiments (to the best of the author s knowledge) have shown this sinusoidal pattern with a maximum and minima separated by twelve hours sidereal time intervals a property which is easily interpreted with absolute earth motion. This is the case, for example, in the recent experiments by Riis *et al*. [11].

The existence of a periodic effect in terms of sidereal time which results from the earth s rotation is thus a strong argument in favour of absolute motion.

Esclangon s Ether Drift Experiments

The proof that Miller s observations do not result from some artifact was provided in 1926 by Esclangon [10].

Esclangon worked in Strasbourg, France with a small astronomical telescope (F = 1.50 cm) which could turn around a vertical axis with an objective lens 0 behind a first mirror M with an axis at 55° to the optical axis F-0. The light beams starting from an horizontal thread F of the reticule are reflected on the mirror M; then, normally on a second mirror M and finally come back to F. A lamp in *f* lights up the thread F which recovers its image reflected through the microscope m. The mirrors M and M and the lamp *l* and telescope form a single rigid unit. The thread F is mobile and its vertical displacements are measured by a micrometric device.

The telescope is horizontal and points first in the north-west direction. Then F and its image are brought together, defining the direction in which the light is reflected on itself. Ten observations are made in this position. The telescope is then immediately pointed at right angles to the north-east and the identical measurement is made again. In each session, therefore, 25 to 29 sets of observations are made.

The experiments showed a systematic difference between north-west and north-east measurements, as one would expect from the difference of orientation of M in the two sets, which results from some absolute motion in space, and as also assumed in the two orthogonal arms of Michelson s experiment. The remarkable fact is that this difference, represented by a point, depends on the sidereal times of the two compared sets of experiments, as clearly results from the 150 sets of observations, corresponding to 40,000 measurements. The differences P(north-west) P (north-east) are measured in terms of sidereal hours. These differences vary between 0 .036 and +0 .036 for 3 hours and 15 hours and vanish (exactly as in Michelson s and Miller s experiments) around 9 hours and 21 hours. A simple calculation shows both sets of measurements are quantitatively similar. Such experiments can easily be redone with lasers, and their precision (in the author s opinion) would be sufficient to detect (with the reduced values that result from Relativity Theory) the earth s orbital (~30 km s^{1}) and absolute (~300 km s^{1}) motions given by astronomical observations.

The existence of absolute motion (with respect to S_o) is corroborated by the fact that the Newton bucket, Foucauld pendulum, Michelson-Gale [13] and Sagnac [14] experiments show evidence of absolute rotation with respect to the most distant background galactic objects. These experiments introduce accelerations and thus should be discussed within the framework of General Relativity Theory, but the introduction of $m_\gamma \neq 0$ nevertheless casts new light on this type of observations.

It should be noted that if we define the local absolute inertial frame S_o by means of a set of 4 axes B^ξ_μ (*i.e.* unitary orthogonal axes) as proposed by Einstein *et al.* [15], another inertial frame *S* designated by b^ξ_μ, is defined with respect to S_o by a complex three dimensional rotation (which carries b^ξ_μ onto B^ξ_μ), *i.e.* by three complex Euler angles which define the corresponding Lorentz transformation. The Lorentz-Fitzgerald rod contraction and clock retardation are thus real effects due to the motion of *S* with respect to S_o and their values in any other frame can be derived therefrom. If one approximates a curved worldline accelerated non-zero mass particle (*i.e.* a photon) by a set of successive small Lorentz transformations, one can utilize equations (3) and (4) to calculate the observed results.

Following Michelson, if we start 1) from the hypothesis of a fixed ether equivalent to the absolute inertial frame S_o in which the earth rotates; and 2) from the fact that this rotation is very slow ($\omega = 73$ microradians s^{1}), we see that the second term in the denominator of equation (4) can be neglected and we can use the relation $\bar{\varepsilon} = \pm \mathbf{v}_{1,2}$ with $c_v \equiv c$.

In the case of the Michelson-Gale experiment of 1925, if v_1 and v_2 are the circumferential velocities of the earth at the northern and southern sides of the spherical rectangle with sides l_1, l_2, then the classical difference in the time required for the two beams to complete the loop in opposite directions is, with our notation, $\Delta t \equiv 2(l_2 v_2)/c$, with a corresponding fringe shift

$$\Delta = \left[\left(4l \cdot h \sin\varphi / c\lambda\right)\right]\omega \qquad (5)$$

where ω is the angular velocity of the earth s rotation, l and h are the sides of the rectangle, φ the geographic latitude and $\lambda = 5.700$ Å.

Obviously, the preceding experiment is a particular type of the famous Sagnac experiment of 1913, with a rotating interferometer (with a polygonal interference loop traversed in opposite directions) rotating at high speed [14]. Here, too the experiment apparently confirmed the classical expression. As is well known, this can be directly justified in Einstein s General Relativity Theory (which predicts a shift proportional to the angular velocity and to the area enclosed by the light path, so that we recover the shift of equation (5), not because the velocity of the two beams is different, but because they each have their own proper times. With $m_\gamma = 0$, we can also justify (5). Assuming the curved world paths of the opposite photons reduce to a circle of radius r, a circle which can be represented by a succession of very small displacements (*i.e.* a succession of Lorentz transformations), we see that the phase difference corresponds to

$$\begin{aligned} &2\pi\left\{1 - \left[\omega \cdot (r \cdot c_\nu)\right] \cdot c^{-2}\right\}\left\{c_\nu - \omega \cdot r\right\}^{-1} - \\ &-2\pi r\left\{+\frac{(\omega r) \cdot c_\nu}{c^2}\right\}\left\{c_\nu - \omega r\right\}^{-1} \qquad (6) \\ &= \frac{2\pi r}{c_\mu} \end{aligned}$$

Relation (6) implies that the Einstein-de Broglie model of light can be tested with a Sagnac interferometer. Indeed, working with a given frequency ν, we see that:

1. The fringe shift given by relation (6) is only valid for $v << c$ and any increases in angular velocity should show (in that model) that the ωr terms decrease when ω increases.
2. The Sagnac interferometer can, in principle, also be used to detect the velocity of orientation of the absolute inertial frame S_o as well as the orbital and absolute values of the earth s motion within this local absolute space-time. The model also predicts the existence of a second order oscillation in the fringe shift (first observed by Michelson) during the sidereal day, as will be discussed in a subsequent publication.

Conclusion

We conclude with the remark that in physics one should be careful to distinguish facts from interpretation: a point strongly emphasized by Mermin in a remarkable paper published in a recent issue (April 1996) of *Physics Today* (16). If, as this author believes, experimental physics reveals an objective reality which exists independently of observers (*i.e.* real facts) the situation of theoretical physics is ambiguous. It helps to interpret and discover new facts, but it is never secure by itself since it can always be destabilized by new facts and new theories. The questions raised in this paper (Are Michelson s and Miller s results true or not? Are they compatible with Einstein s initial presentation of Relativity?) should now be retested by experiments. Like all theoretical statements, the author s answer (Yes, the results are correct. Yes, a real ether exists and it is compatible with Relativity, provided one introduces a non-zero photon mass.) should now be confronted with experimental evidence. There should exist no Golems in modern science.

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