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Can a Michelson-Morley Experiment Designed with Current Solar Velocity Distinguish between Non-Relativistic and Relativistic Theories?

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Abstract

If Michelson were to answer the question posed in the title, given the line of reasoning he used in 1881, Michelson would seat at his desktop computer to calculate the expected fringeshifts for several solar speeds around 400 km/s and various directions of motion. Present author did exactly the same in 2001 to plan his repetition of Michelson and Morley's (MM) 1887 experiment. The paper sketchedly summarizes the procedure to calculate expected fringeshifts in the MM interferometer for solar speeds available at Miller's epoch. In a pre-relativistic context, amplitudes of several fringeshifts may be expected in both MM and Miller experiments. However, all interferometer experiments up to 1930 were designed under the (incorrect from a modern viewpoint) assumption that fringeshifts would be smaller than one fringe-width. The inescapable conclusion is that those experiments were not appropriate to measure the true value of solar motion, always yielding a small, but lower than expected, value for solar speed. The ensuing "negative" interpretation led to the birth of relativity theory and to a new series of experiments implicitly designed to test the relativistic hypothesis of length-contraction, while the earlier "positive" experiments were designed to test a different hypothesis: whether the motion of Earth relative to some preferred frame can be measured using an interferometer of constant dimensions. With the benefit of hindsight this writer repeated the MM experiment, correcting main weaknesses identified up to the Michelson-Morley-Miller (MMM) measurements at Mount Wilson from April 1925 to February 1926. A new possible reinterpretation of the MMM data as a sequence of stationary measurements is pointed out. Our Michelson-Morley-Miller-Munera (MMMM) experiment at Bogota (Colombia) from January 2003 to June 2005 gave values for solar absolute velocity in the same range as those obtained by astronomical means. Surprisingly, our results are compatible with modern third-party MM-type experiments designed and interpreted within relativistic contexts. Thus, a so far unexplored possibility arises: can interferometric experiments distinguish between pre-relativistic and relativistic theories? Our answer is negative.

Keywords

Michelson-Morley Experiment, Crucial Physics Experiments, Foundations of Physics, Absolute Solar Velocity, Absolute Motion of Earth, Correctness of MM Positive Experiments, Correctness of MM Negative Experiments

1. Introduction: CMB and Interferometer Experiments Are Non-Contradictory

In a recent paper Prilepskikh [1] correctly pinpointed the patent contradiction between two sets of empirical evidence related to the seat of electromagnetic phenomena. On one side, the conventional "negative" interpretation of the pioneering interferometric experiments by Michelson in 1881 [2] and Michelson and Morley in 1887 [3] (MM henceforth), and on the other side, the discovery reported in 1965 by Penzias and Wilson of cosmic microwave background radiation (CMB) [4], whose local anisotropy is interpreted as motion of solar system relative to a frame of reference attached to the CMB. Solar velocity approximately is 384 km/s, in the direction of galactic coordinates (264˚, 48˚) [5]. Since the Local Group of galaxies (including our Milky Way) seems to be moving with a higher speed, it is quite possible that the CMB-frame itself is also moving relative to something else, say a preferred frame, see [6] and references therein.

To solve the posited contradiction, Prilepskikh reinterprets Michelson's 1881 analysis [2] in terms of Doppler's effect and "*space-time* '*quantization*' *of radiation by wavelength-periods*", and concludes that the conventional "null" interpretation of Michelson's experiment is compatible with existence of motionless non-entrained ether. Thus, there is no contradiction with terrestrial and solar motion relative to CMB.

Technical details in Prilepskikh's paper [1] are not addressed here. Rather, it is noted that Doppler's effect was not a fully accepted theory in 1881 when Michelson was at Postdam carrying out his experiment under Helmholtz supervision. During the period 1872-1892 Vogel studied optical effects at the Observatory, also in Postdam, work that eventually led to the acceptance of Doppler's laws ([7], p 34). In the 19th century Riemann introduced the notion of four dimensions (space and time), while the current notion of spacetime is due to Einstein in the second decade of the 20th century.

From logical and historical considerations, this writer prefers to solve the contradiction, if any, with the technical, mathematical and philosophical means that Michelson had at his disposal in 1881 [8]. First thing to stress is that in the 1880s relativity theory did not exist. This means that the analysis of Michelson's expectations has to be done without including relativistic effects. As clearly documented in [8], the historical facts are that both Lorentz length-contraction and Poincaré's principle of relativity were proposed to explain the null interpretation of Michelson's 1881 and MM's 1887 experiments.

Second point to stress is that, strictly speaking, there is no contradiction. Indeed, in all cases the data reduction process yielded a non-zero speed of Earth relative to the preferred frame that was lower than expected, but never zero [9] [10] [11] [12]—fact explicitly stated by Miller in several occassions [13]. This also applies both to the initial 1881 Postdam experiment [2], and to the short 1887 Michelson and Morley six-hour Cleveland experiment involving only 36 turns of the interferometer [3] (see Section 2). Furthermore, there are no error bars in the 1887 MM experiment, which had a significant error spread consistent both with a negative result, and with much larger values close to the expected 30 km/s [11] [12].

A third extremely significant aspect, usually overlooked, is that the vast majority of pretended "repetitions" of the MM experiment are not true repetitions in a strict sense. The reason is quite simple. After Einstein's formulated his special relativity in 1905, the data reduction process in those experiments incorporates corrections for the presumed length-contraction in the arms of the interferometer [9]. Thus, actually there are two different families of interferometric experiments, which have been treated so far as a single family, namely:

(A) Classical or pre-relativistic interferometric experiments, as Michelson's 1881 [2], MM's 1887 [3], and Morley-Miller and Miller's experiments [13], were all designed under the implicit premise that dimensions of the apparatus do not change as a result of absolute terrestrial motion (of course, dimensions may change by environmental or other causes). Since Earth's orbital and rotational motions are well-known, the problem reduces to testing for the value of solar motion [8]. For the value of solar velocity available in 1881 the expected fringeshifts were lower than one fringe-width (see Section 2.1). A variety of hypothesis were explicitly tested in Miller's work from 1902 to early April 1925 [13]. For his final campaign at Mount Wilson in April, August and September 1925, and February 1926, Miller finally tested for solar velocity without preconceived ideas (see Section 2.4), this will be called henceforth the Michelson-Morley-Miller (MMM) experiment. For the values of solar velocity available today, significant fringeshifts (*i.e.*, larger than one fringe-width) are expected in the large interferometers used in the MM and MMM-experiments [14] [15]. Our Michelson-Morley-Miller-Munera (MMMM) experiment also belongs to this category (see Section 3). Earth's velocity and the ensuing solar velocity are calculated from the observed large fringeshifts. These are the so-called "positive" experiments.

(B) Relativistic interferometric experiments assume that the Lorentz-Fitzgerald length-contraction is a physical phenomenon that continuously modifies the length of the arms of the apparatus (hence, the lengths of the two optical paths) as Earth moves in space. The so-called "negative" experiments are implicitly designed to test the hypothesis that the outcome of the experiment is "null", that is, that the expected fringeshift is zero (exactly). Any deviation from the expected value (hopefully small, *i.e.*, less than one fringe-width) is attributed to experimental error. In the Kennedy and Thorndyke experiment [9] corrections for time dilation are also included during data reduction.

The distinction between the two families identified above has been missed because the apparatus and the experimental setup are the same in both cases. During the experimental phase, the only difference is in the recording of the observed fringeshift: the whole fringeshift (*i.e.*, an integer plus a fraction) in case (A), and in case (B) the fractional part of the fringeshift only. However, the process of data reduction is quite different: Earth's velocity is directly calculated from the observed large fringeshift in case (A), while in case (B) the observed fractional fringeshifts are interpreted as experimental errors relative to expected theoretical fringeshifts calculated with relativistic corrections for length of each arm moving at different velocity (orientation and speed) relative to some reference frame. Such velocity is obtained from external sources. Hence, the small observed residual error is attributed to: 1) accuracy of the value of speed used for the relativistic length-contraction corrections, 2) usual experimental errors, and 3) new unknown phenomena.

Turning now to the rhetorical question in the title of this paper: how would Michelson change the design of his 1881 and 1887 experiments with the information available today? Since Michelson was a top-class experimenter, we can answer in the same rhetorical mood that he would notice that the 1881 measurements at discrete positions of the apparatus requiring separate calibrations would not be appropriate, and he would implement continuous rotation of the interferometer relative to the preferred frame right since the initial 1881 experiment. Moreover, motion of reference fringe would be carefully monitored to identify shifts larger than one fringe-width. Furthermore, such large shifts would not be entirely attributed to usual experimental effects, say variation of temperature in the laboratory.

Returning to the historical record, it seems that Michelson's 1881 original assumption of recording only the fractional part of the shift was never revisited by Michelson, Morley or Miller. More than 40 years later, prompted by Nassau and Morse's work [16], Miller had a glimpse at the significant impact of solar motion ([13], pp 222-228), and implemented continuous 24 hr-measurement of fringeshifts for his MMM-experiment (see Section 2.4, and figures 1 and 2). Unfortunately, Miller continued recording the fractional-part of the fringeshift only.

Our own predictions take full account of solar motion as reported in 2002 [14] and 2006 [15]. Since Earth herself may provide a steady continuous slow rotation of the interferometer relative to the preferred frame, it follows that rotation of the apparatus relative to the laboratory is superfluous. Thus, the interferometer for our MMMM-experiment had short arms (2 meter long) and was, for the first time, stationary in the laboratory [15] [17] [18] [19] [20] (see Section 3).

Modern experiments based on different physical phenomena [21] [22] may exhibit in the raw data exactly the same structure as our own positive results [18] [19] [20]. However, they are interpreted in the conventional negative context. For instance, in the well-controlled 2002 experiment at Stanford University using cryogenic resonant microwave cavities, the evident positive results were dismissed as unexplained "*mechanical disturbances*" that were subtracted from raw data, leading to a remaining white noise that was interpreted as their expected "null" result [21].

2. The Classical Pre-Relativistic Interferometric Experiments

In a general overview of the MM-type experiments [9] written by present author in 1998, some issues were not identified, and some weaknesses were not stressed enough, say, the lack of error analysis in MM experiment [11] [12]. Other issues as the possible existence of large fringeshifts (*i.e.*, larger than one wavelength) between two consecutive positions of the interferometer became obvious during the design in 2001 [14] and execution of our MMMM-experiment [15] [17]. All "positive" experiments are designed according to two classical postulates: (a) Light propagates isotropically with constant speed c relative to a preferred frame anchored to Newton's fixed stars, and (b) Velocity of a laboratory at Earth's surface (V_L) relative to the fixed stars frame is the vector addition of terrestrial velocity (V_E) and solar velocity (V_S). In turn, neglecting minor effects, V_E is the vector composition of orbital (V_O) and rotational (V_R) velocities, while V_S is formed by orbital motion around the center of our galaxy (speed V_G = 254 km/s), plus motion of Milky Way's center-of-mass relative to the fixed stars. Upper panel A in **Figure 1** illustrates the expected 24-hr periodic effect arising from terrestrial rotation V_R, while central panel B illustrates the expected annual periodic effect associated to V_O. Both periodicities were observed in the MMM and MMMM-experiments. At the time-scales of these experiments, solar velocity V_S is an unknown constant to be determined from the data. Lower panel C in **Figure 1** illustrates projections V_1 and V_2 of laboratory velocity V_L for different interferometer positions (angle relative to local east), as in the MM and MMM-experiments; panel C is not relevant for the MMMM-experiment, where the interferometer is at rest in the laboratory. In the context of "negative" experiments, panel C shows the time-dependent projections $V_1(t)$ and $V_2(t)$ upon arms A_1 and A_2 of the apparatus. $V_1(t)$ and $V_2(t)$ are used to calculate the respective relativistic length-corrections; laboratory velocity V_L is an outside datum.

2.1. The 1881 Michelson Experiment at Berlin and Postdam (Germany)

The arms of the interferometer used by Michelson in 1881 had a length L = 1.2 m, equivalent to approximately 2 E+6 wave-lengths of yellow light, chosen as the scale for his study. The theoretical basis for the experiment was: "*Assuming then that the ether is at rest, the earth moving through it, the time required for light to pass from one point to another on the earth's surface, would depend on the*

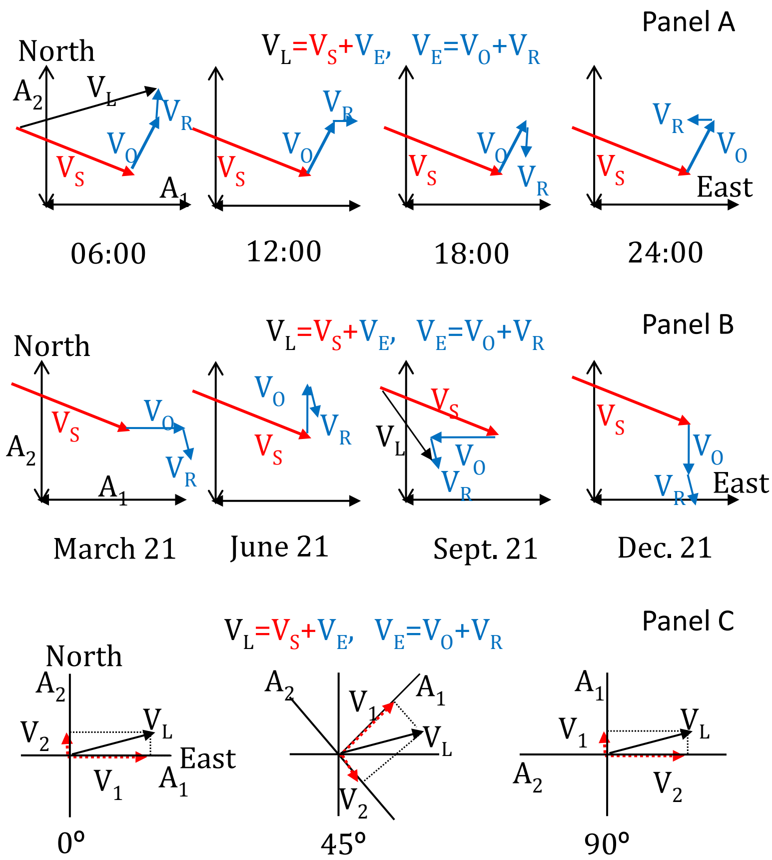

Figure 1. Illustration of diurnal and annual fringeshift periodic effects due to Earth's rotational ($\boldsymbol{V}_R$) and orbital ($\boldsymbol{V}_O$) motion (panels A and B respectively). Panel C: variation of projections V_1 and V_2 of absolute velocity $\boldsymbol{V}_L$ of a laboratory on Earth's surface upon arms 1 and 2 for different positions of an interferometer in rotation relative to the laboratory. Velocity arrows are not to scale: orbital speed V_O is 29.8 km/s, while V_S is at least one order of magnitude higher than V_O, and V_R is about two orders of magnitude lower than V_O.

direction in which it travels. Let c be the velocity of light, v = the speed of the earth with respect to the ether" ([2], p 120), underlining added, and the modern notation c for light velocity was used instead of Michelson's V. There are two tacit assumptions in previous statement: (a) Ether is at rest relative to something, that in 1881 most likely was Newton's absolute space, and (b) Light moves with speed c that is isotropic so that it has the same value any time of day at any epoch of the year, relative to some unspecified frame of reference, that may be Newton's preferred frame. Michelson continued: "*Suppose the direction of the line joining the two points to coincide with the direction of earth's motion*" ([2], p 120). Based on this direction (unknown in general), Michelson obtained equations for the time of light-travel along the arm of the interferometer aligned with this direction. As a numerical example Michelson calculated the time delay "*considering only the velocity of the earth in its orbit*" ([2], p 121). According to Michelson "*the actual distance the light travels in the first case is greater than in the second, by the quantity*" Δf given by

$$\Delta f = 2L\beta^2 \text{ where } \beta = v/c \tag{1}$$

Regarding the other arm of the interferometer Michelson stated: "*if, however, the light had traveled in a direction at right angles to the earth's motion it would be entirely unaffected*", and again at the end of same page: "*the other pencil being at right angles to the motion would not be afffected*" ([2], p 121), underlinings added. As independently noted by M. A. Potier in 1881 and by H. A. Lorentz in 1886, Michelson's analysis for the transverse arm is not correct regarding the underlined words above. Michelson acknowledged this error in his theory for the MM 1887 experiment ([3], p 334-336).

However, the final result presented in 1887, neglecting all terms above second order is exactly the same as in 1881. In Michelson words: "*if now the the whole apparatus be turned through* 90˚ *the difference will be in the opposite direction, hence the displacement of the interference fringes should be*" Δf given by equation (1) above ([3], p 336).

Michelson treated velocity of Earth's center of mass $V_{CM} = V_O + V_S$ as the vector addition of two components: (a) orbital motion with approximate speed V_O = 30 km/s along the plane of the ecliptic, plus (b) solar motion V_S toward constellation Hercules, that for early April 1881 was at an angle of 26˚ relative to Earth's terrestrial equatorial plane ([2], p 124). He explicitly stated that "*if the apparatus be so placed that the arms point north and east at noon, the arm pointing east would coincide with the resultant motion, and the other would be at right angles. Therefore, if at this time the apparatus be rotated* 90˚, *the displacement of the fringes should be twice* 8/100 *or* 0.16 *of the distance between the fringes*" emphasis in the original ([2], p 125).

Michelson also considered a second alternative: "*if on the other hand, the proper motion of the sun is small compared to the earth's motion the displacement should be* 6/10 *of* 0.08 *or* 0.048" ([2], p 125). And decided to average the two possibilities: "*taking the mean of these two numbers as the most probable, we may say that the displacement to be looked for is not far from one-tenth the distance between the fringes*" ([2], p 125).

Unfortunately, Michelson missed a third scenario, which is logically and physically possible, namely: solar speed V_S >> 30 km/s, and/or the direction of solar motion is not towards Hercules. As accepted today, solar speed relative to a preferred frame is V_S = 384 km/s according to [5], or V_S = 390 km/s according to [23]. There are also higher estimates: V_S > 600 km/s [24] [25] [26]. This means that $\beta = v/c$ = 390/300,000,000 increases at least by a factor of 13 relative to Michelson's calculations. Thus Michelson's longitudinal fringe shift Δf = 0.16 becomes $\Delta f = 0.16 \times 13 \times 13 = 27$, *i.e.*, much larger than one fringeshift!

Thus, the three classical interferometric experiments [2] [3] [13] were designed under the (incorrect from a modern viewpoint) assumption that expected fringeshifts were smaller than one fringe-width.

For completeness, let us mention that the 1881 interferometer was a static apparatus that was aligned in 45˚ steps along different local directions North, Northeast, East, etc. Each measurement was independent of the next, and it was impossible for Michelson to know how many fringes shifted from a given position to the next. Thus, from the viewpoint of modern knowledge regarding the speed of solar motion, it is sad to say that Michelson's expectations (*i.e.*, a fringeshift about 0.1 fringe-widths, as quoted above) could not be determined from his experimental setup.

2.2. The 1887 MM-Experiment at Cleveland (Ohio)

For the MM-experiment there was a significant change in the design of the apparatus that was mounted upon a stone floating in mercury continuously rotating during the measurements. Length of the optical path along each arm was increased to $L = 11$ meters. Position of reference fringe was read by an observer continuously walking around the apparatus with same angular speed as the stone, and looking through a telescope every 22.5˚. As in the 1881 experiment, it was assumed (without any observational evidence) that the reference fringe always shifted by less than one fringe-width. This is an almost unbelievable assumption because in 1887 the 11-meter long arms of the apparatus were ten times longer than in 1881, so that in the case of motion toward Hercules only, the expected longitudinal fringeshift according to Equation (1) and Michelson's calculation mentioned in previous Section 2.1 would be $\Delta f = 0.16 \times 10 = 1.6$ fringes!

It is quite surprising that MM decided to ignore the small motion toward Hercules: "*only the orbital motion of the earth is considered. If this is combined with the motion of the solar system, concerning which but little is known with certainty, the result would have to be modified; and it is just possible that the resultant velocity at the time of the observations was small though the chances are much against it. The experiment will therefore be repeated at intervals of three months, and thus all uncertainty will be avoided*" ([3], p 341), undelinings added. However, the experiment never was repeated at the promised three-month intervals. From calculations in previous Section 2.1 without including solar motion (*i.e.*, with orbital motion only) the "expected" fringeshift would $\Delta f = 0.048 \times 10 = 0.48$ fringe-width. However, such value is just the lower limit in the set of all possible fringeshifts.

Granted, the true value of solar speed V_S was unknown in 1887, and even in 2022 it is not completely known. Instead of assuming $V_S = 0$, a standard and correct approach in experimental physics is to estimate possible outcomes of the experiment for different values of V_S, say {0, 30, 60, ..., 300, 600, ..., 3000 km/s}. Using Equation (1), values of Δf for each V_S were easy to calculate in 1881 and 1887. Evidently, for the majority of values of V_S the expected fringeshift would be larger than 1.

The time-dependent velocity of Earth's center of mass is $V_{CM} = V_O + V_S$, where orbital velocity V_O is a known time-dependent function, and solar velocity V_S is an (unknown) constant at the time-scale of the interferometric experiments discussed here. At a laboratory located at longitude ϕ and latitude θ on the surface of Earth, velocity V_{CM} may be decomposed into a horizontal component V_I (t; ϕ, θ) tangential to the surface of Earth (*i.e.*, parallell to the plane of the interferometer) and a vertical component V_V (t; ϕ, θ), perpendicular to the floor.

Left panel in **Figure 2** shows the magnitude of V_I at a laboratory in Cleveland on July 8/1887 over the 24 hours of the day, for four different values of solar velocity: (a) V_S = 30 km/s in the direction of right ascension $\alpha = 270^\circ$, declination $\delta = 26^\circ$, which is used as an approximate representation of solar motion toward Hercules constellation as in the 1881 Postdam experiment. (b) V_S = 0, *i.e.*, only orbital motion of Earth as in the 1887 MM-experiment. (c) Miller-N: V_S = 200 km/s toward the northern galactic apex at $\alpha = 255^\circ$, $\delta = 68^\circ$ ([13], p 232). (d) Miller-S: V_S = 208 km/s toward the southern galactic apex at $\alpha = 73.5^\circ$, $\delta = -70.55^\circ$ ([13], p 234).

Left and central panels in **Figure 2** show that both V_I and fringeshift curves may have one or two cycles over a single day depending upon the speed and orientation of V_S. Examples for other values of V_s appear in ([14], fig 1, p 476). For the physically incorrect case with V_S = 0 there are two cycles (second row from top in left and central panels). As V_S increases the depth of one of the minima slowly evolves (first row in left and central panels for V_S = 30 km/s). As explained in [14] (see equation 32, p 480 in Section 4), there are values of V_S at which one of the minimum fringeshift values dissappears as it merges with the

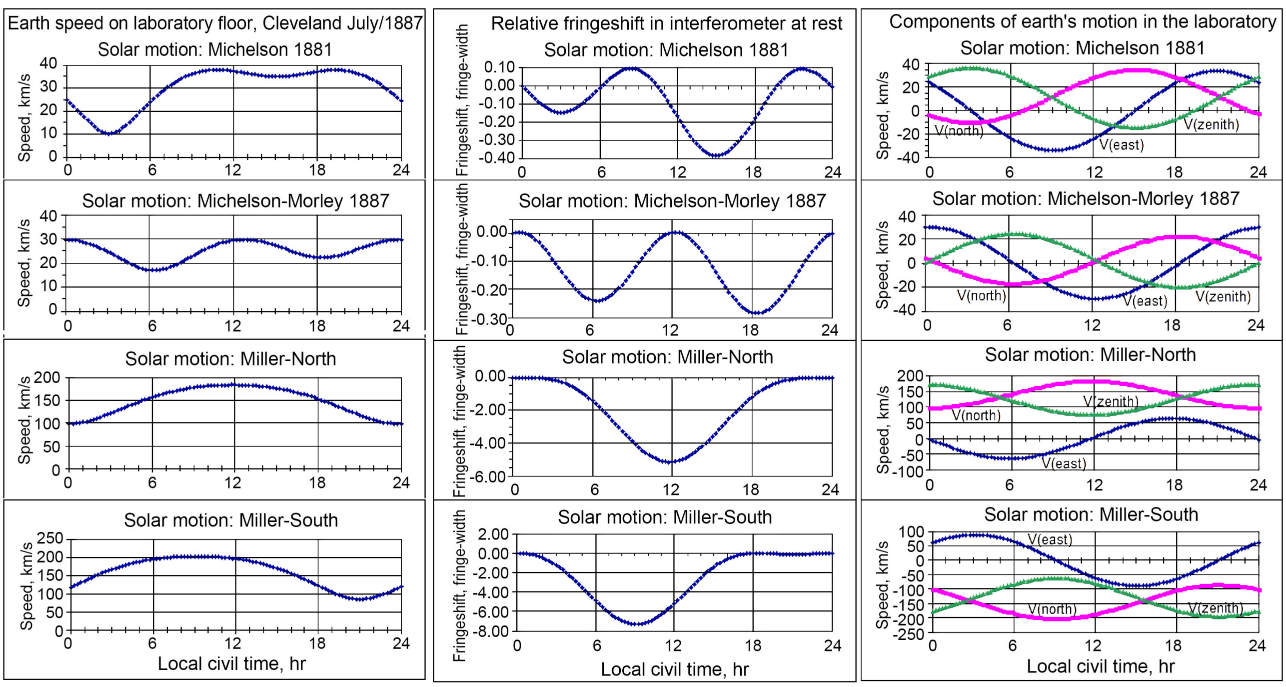

Figure 2. Effect of solar velocity (see text) upon a MM interferometer at rest in Cleveland (Ohio) on July 8/1887 during the MM-experiment. Left panel: magnitude of V_I the absolute motion of Earth's center-of-mass parallel to the floor of the laboratory. Central panel: relative fringeshift in fringe-widths. Right panel: daily variation of Cartesian components of V_{CM} at MM's laboratory. High values of solar speed (two lower rows) lead to fringeshifts larger than one fringe-width; maximum value is 8 fringe-width for Miller-S case (see central panel, bottom row).

two adjacent maxima (*i.e.*, three gradients of the curve become zero at same place). For such particular values of solar velocity the V_I and fringeshift curves have only one diurnal cycle. Also, location of maxima and minima significantly vary according to orientation of solar motion (α, δ).

Central panel in **Figure 2** shows the fringe shifts predicted in a MM interferometer at rest, *i.e.*, without rotation relative to the floor of a laboratory in Cleveland on July 8/1887. Of course, such predictions do not refer to MM-experiment where the interferometer was in rotation relative to the laboratory. There is, however, a connection between both types of experiments that is explained in Section 2.5. For an apparatus at rest, cases (a) and (b) in **Figure 2** calculated with the physically incorrect small solar speeds predict maximum and minimum amplitudes lower than one fringe-width. For solar speeds around 200 km/s predicted fringeshifts are significantly higher than one fringe-width. It may be recalled in passing that such speeds were obtained by Miller from his data by using a questionable ad hoc procedure. Of course, for higher solar speeds around 390 km/s, as currently accepted [5] [23], the expected fringeshifts are larger.

Shape of fringeshift curves in central panel of **Figure 2** is of paramount importance. Indeed, the only case showing a maximum at noon, and a minimum of equal magnitude at 6 p.m. corresponds to the physically incorrect assumption of a Sun at rest (*i.e.*, $V_S = 0$) as in case b. Since Michelson used such (incorrect) assumption in the derivation of Equation (1) above, it means that such expression is not physically correct, and invalidates its usage for the interpretation of the MM-experiment and for all the experiments carried out by Miller ([13], p 227). Further comments in next subsections.

For completeness, right panel in **Figure 2** shows the three Cartesian components of Earth's center of mass velocity V_{CM} relative to a laboratory on the surface of Earth: North, East and Zenith. V_I is the projection of V_{CM} upon the interferometer plane, given by the vector addition of V (North) and V (East). Magnitude of V_I is in the left panel of **Figure 2**.

2.3. Morley and Miller Experiments at Cleveland (Ohio) from 1902 to 1906

After Michelson left Cleveland for Chicago, Morley continued the experiments with Dayton C. Miller, a Princeton graduate. Altogether, Morley and Miller completed 995 turns of the interferometer from 1902 to 1906 ([13], pp 208-217), [27]. For the 260 turns in July 1904 the analysis "*was based upon the effect to be expected from the combination of the diurnal and annual motions of the earth, together with the presumed motion of the solar system towards the constellation Hercules*". Once again, this is the same small solar speed assumed in all classical interferometric experiments [2] [3] [13]. Morley and Miller found the "*two times of the day when the resultant of these motions, about* 33.5 *kilometers per second, would lie in the plane of the interferometer,* 11:30 *o'clock, A.M., and* 9:00 *o'clock, P.M.*" ([13], p 216, column 1), and, following Michelson, they averaged the A.M. and P.M. readings. However, the two lower graphs in central panel of **Figure 2** show that the method is incorrect for high values of solar speed. Miller discovered the error in the mid 1920s, and in his 1933 overview paper [13] he honestly stated that the "*procedure of* 1904 *was incorrect*" (see page 216, column 2 and figure 11 in page 217).

Despite the said gross errors in data gathering and data reduction, the experiments by Morley and Miller were "positive": "*the morning and evening observations each indicate a velocity of ether drift of about* 7.5 *kilometers per second*" ([13], p 217, column 1).

2.4. Miller's 1921-1926 Experiments at Cleveland (Ohio) and Mount Wilson (California)

Spurred by British observations during the 1919 solar eclipse (that were interpreted as supporting general relativity), Miller decided to resume his experiments, whose "null" interpretation was at the empirical foundations of special relativity ([13], p 217, column 2). Miller carried out measurements at Mount Wilson, near Pasadena (California) in 1921, at Cleveland during 1922-1924, and again at Mount Wilson during 1925-1926, for a grand total of 2327 turns of a steel interferometer.

After the Cleveland campaign Miller reports that "*at the end of year* 1924, *when a solution seemed impossible*, *a <u>complete calculation</u> of the then expected effects*, *for each month of the year*, *was <u>made for the first time</u>. This indicated that the effect should be a maximum about April* 1, *and further*, *that the <u>direction of the effect</u> should*, *in the course of the twenty-four hours of the day*, *<u>rotate completely around the horizon</u>*" underlinings added ([28], p 356). However, still following Michelson, only the apparent solar motion towards Hercules was considered ([13], p 221, column 2). A test at Mount Wilson from March 27 to April 10, 1925 finally demonstrated that absolute solar motion is not the same as the relative local motion towards Hercules ([13], p 222, column 1).

Thus, Miller realized at last that "*it is necessary to determine the <u>variations</u> in the magnitude and in the direction of the ether-drift effect throughout a period of twenty-four hours and at three or more epochs of the year*" emphasis in the original ([13], p 223, column 1). He then designed his new experiment with "*two sets of readings made in each hour through a working day*, *or night*, *of eight hours*" ([13], p 212, column 2). Miller's introduction of frequent readings over a 24-hr period, in experimental sessions of several days at different epochs of the year, was a significant improvement over MM-experiment.

Each set of readings at Mount Wilson lasted about sixteen (16) minutes for twenty turns of the interferometer mounted on a rotating stone floating in mercury, each turn taking forty eight seconds. Thus, every three (3) seconds "*the observer has only one single thing to do…announce the position of the central black fringe with respect to the fiducial point*, *plus or minus*, *in units of a tenth of a fringe width*, *at the instant of the click of the electric sounder*" ([13], p 213, column 1). However, this is easier said than done: the observer had to "*walk in a small circle*, *in the dark*" ([13], p 228, column 2), at the same angular speed as the apparatus, without perturbing the rotating stone in any way, to look through an astronomical telescope whose "*eyepiece is supported on the end of the arm, there being no tube for the telescope…direct reading with the eye was very satisfactory*" ([13], p 220, column 1).

Since Miller continued anchored to Michelson's idea that the expected fringeshift was small, the significant fringeshifts observed at Mount Wilson were entirely attributed to "*temperature drift*". This led Miller to eliminate the (presumably unwanted) fringeshit drift in two steps, both of them visible in the datasheet for September 23/1925 at 03:17A.M. (see figure 8 in ([13], p 213)):

(1) A (questionable, in several senses) on-line modification of one arm of the apparatus, whose length was changed by hanging a small weight at its end, thus flexing it. Since rotation was not stopped, the observer continued collecting data without interruption, despite the obvious fact that flexing would induce vibrations in the metalic arm, thus possibly leading to spurious readings in the position of the reference fringeshift (at the very least during the turn of the apparatus immediately after the flexing). Such modification of the hardware was euphemistically identified as "adjust" in figure 8. In Miller's words: "*the adjustments are maintained so that the central fringe of the field of view… is <u>never more than two fringe widths</u> from the fiducial point*" underlining added ([13], p 212, column 1). In passing, this means that Miller did observe fringeshifts larger than one fringe-width. In the particular case shown in figure 8 there were four adjustments in 16 minutes. And,

(2) During data processing, the readings in every single turn lasting 48 seconds were linearly corrected for the presumed temperature variations during that 48-second-time span. The calculations are shown in the lower part of the datasheet in figure 8, and are further illustrated in figure 9 ([13], p 213). Such corrections were applied despite the fact that temperature in the laboratory was almost constant to an accuracy of 0.1˚ as attested by four thermometers, whose readings were taken at 02:57 and 03:19 (see top part of datasheet in Miller's figure 8).

From the data corrected for temperature drift, Miller calculated Earth's speed using Equation (1), often called the "*elementary theory of the experiment*" ([13], p 227, column 1).

As discussed in Section 2.5 below, without the "adjustments" and without the correction for temperature drift, the datasheet for September 23, 1925 at 03:17 A.M. would show a cumulative net fringeshift to the left of 6.1 fringe-widths in 16 minutes ([8], pp 33-34). By any standard, this was a significantly large fringeshift!

The original datasheets of the MMM-experiment (about three hundred pages) were recently unearthed by James De Meo at the Physics Department of Case Western Reserve University (CWRU) and moved to the general CWRU archive ([29], p 308). They all show "adjustments" similar to those discussed above for September 23/1925. Present writer was tempted to reverse Miller's "*adjustments*" in the 300 data sheets. Instead, it was preferred to undertake our MMMM-experiment, summarized in next Section 3.

For further comments on other systematic errors in Miller's experiment see ([9], Section 2.1) and [10]. In particular, as seen in **Figure 2**, the curves of V_I and fringeshift versus time are not sinusoidal in general, and their shape depends on the direction (α, δ) of solar motion. This leads to a 24-hr component in the orientation of V_I upon the plane of the interferometer as a function of angle ω, the direction from local east. Instead of Michelson's Equation (1) above, fringeshift Δf is given in first approximation by Equation (2) here (see equations 2 and 3 in [9] or eq. 2 in ([10], p 192), and for additional details Section 3 in ([14], p 472-478) and equation 20 in Sections 2.2 and 2.3 in ([15], p 75-79)):

$$\Delta f = \frac{2L\beta_I^2}{\lambda}\cos 2\omega \text{ where } \tan\omega = \frac{V(\text{north})}{V(\text{east})}, \beta_I = \frac{V_I}{c} \tag{2}$$

Wavelenght of light used in the interferometer is λ, and length of the arm is L. In the relativistic context of the "negative" experiments, there are phase effects somewhat similar to Equation (2), see Sfarti's equation 3.1 in [30].

Despite all shortcomings, Miller's experiment was "positive": "*these experiments had given conclusive evidence of a* <u>*real*</u> *effect which was systematic but which was* <u>*small in magnitude*</u> *and was* <u>*inexplicable as to its azimuth*</u>" underlinings added ([13], p 228, column 1). To get realistic values for solar speed from his experiment, Miller had to introduce by hand a factor of reduction k "*which has so far remained inexplicable*" ([13], p 234, column 2). It is our contention that without the "adjustments" the MMM-experiment would have been successful.

In our opinion, a given fringeshift is due in part to true motion of Earth relative to a preferred frame and partially to atmospheric variations due to changes in temperature, pressure and air composition (water vapour, CO_2 and other contaminating gases, dust, etc.). In contrast, the possible effect of variations of atmospheric pressure was not explicitly mentioned by Michelson, MM or Miller. The importance of the index of refraction along the light path has been stressed also by the group led by Consoli in Italy [6]. They additionally suggest a possible non-zero refractivity of the vacuum. If the latter is confirmed by experiment it could be interpreted, in my opinion, as the refractivity of a non-material energy-like aether.

Summarizing and frankly speaking, in the short three-second interval between readings in the MMM-experiment, the observer barely had time to raise his head from the eye piece, jump from one reading position to the next, turn and lower again his head towards the eyepiece, identify and shout to the scribe an approximate value (in tenths of a fringe-width) for the position of the central fringeshift relative to the pointer. Also, from the rightside photograph in figure 7 ([13], p 211) showing six black fringes in the field of view (without any scale), it seems hard to achieve the reported 0.1 fringe-width accuracy. It is not credible that a human observer can walk in circles during sixteen (16) minutes with his head sideways and attached to the eyepiece continuously watching a given reference fringe. Despite these caveats, Miller's data is taken at face value in the analysis carried out in next Section 2.5.

In the same vein, Sir Oliver Lodge wrote a century ago: "*it is rather surprising that the readings were made by a peripatetic observer, with the instrument in constant and not very slow rotation…one would have thought that a stoppage of the frame and a reading of the fringes by a seated observer in many azimuths, would have been more satisfactory*" underlining added ([31], p 854, column 2). In fairness to Miller, he did consider the possibility of having a photographic register of fringeshift position, idea abandoned because luminosity did not suffice for good quality photographs in the rotating interferometer ([13], p 220, column 1).

2.5. A Reinterpretation of MMM Daily Data as a Sequence of 16 Interferometers at Rest

Professor Lodge's suggestion amounts to an interferometer at rest in the laboratory, with the "*many azimuths*" provided by earth's rotation, idea used in our MMMM-experiment (see next Section 3). Instead of Miller's "temperature drift" interpretation, let us reinterpret the drifts in the raw data of the MMM-experiment as real fringeshifts in a group of 16 stationary interferometers at different orientations relative to the laboratory.

Neglecting the effect of the (very small) speed of rotation of the interferometer relative to the laboratory, each one of the 17 columns in anyone of Miller's datasheets may be viewed as a set of 20 readings taken at intervals of 48 seconds in an interferometer at rest in the laboratory. Each column corresponds to a different orientation of the apparatus relative to the laboratory, namely: column 1 is an interferometer oriented with the telescope towards local north. Column 2 is an interferometer with the telescope towards local north plus 22.5˚ counterclockwise, and so on for the other columns. For instance, column 5 is a 90˚ rotation that places the telescope towards local west. Last column 17 is a 360˚ rotation that returns the apparatus to the original orientation towards north.

Let us focus here on the interferometer with the telescope oriented north. Columns 3 and 4 in **Table 1** correspond to columns 1 and 17 in the datasheet for September 23/1925 at 03:17 A.M. local mean time ([13], fig 8, p 213). Values are positive/negative according to the right/left position of the reference fringe relative to the pointer. Column 2 in **Table 1** is time t in seconds, elapsed since the beginning of the first turn, for a total of 960 s at the end of the twentieth turn.

Note that column 17 in Miller's figure 8 contains the last value of a turn, which also is the first value for the next turn in column 1. This should occur for all values within a given session. However, as already noted in previous Section 2.4, this is not the case here because Miller (incorrectly) modified in three occassions the length of one of the arms of the interferometer during the 20 turns of the session. The word "adjust" in turn 5 means that at the end of the turn one arm of the interferometer was flexed, in such a manner that the reading "−15" in

Table 1. Miller's readings for the interferometer at rest with telescope pointing north at Mount Wilson on September 23/1925, 03:17A.M. local mean time ([13], figure 8, page 213).

1	2	3	4	5	6	7	8	9
Turn j	$t(j)$, elapsed time, s	Y = reference fringe position		Comment	Y = reference fringe position			
					Interferometer			
		Column 1 (figure 8)	Column 17 (figure 8)		1	2	3	4
1	0	+10	+7		+10			
2	48	+7	+1		+7			
3	96	+1	−4		+1			
4	144	−4	−13		−4			
5	192	−13	−15	Adjust	−13			
6	240	0	+8		−15	0		
7	288	+8	−2			+8		
8	336	−2	−11			−2		
9	384	−11	−10	Adjust		−11		
10	432	+8	−1			−10	+8	
11	480	−1	0				−1	
12	528	0	+9				0	
13	576	+9	+7				+9	
14	624	+7	+10				+7	
15	672	+10	0				+10	
16	720	0	−4				0	
17	768	−4	−10				−4	
18	816	−10	−12				−10	
19	864	−12	−21	Adjust			−12	
20	912	+1	+4				−21	+1
	960							+4

column 17 was changed into "0" which now appears at the beginning of turn 6. Table 1 also shows similar modifications of the apparatus at the end of turns 9 and 19.

The net effect of Miller's "adjustments" is that, as a matter of fact, there are four different apparatuses during the set of readings under consideration. Apparatus 1 was used for turns 1 to 5, apparatus 2 for turns 6 to 9, apparatus 3 for turns 10 to 19, and apparatus 4 for last turn 20. Individual readings for the reference fringe position in each apparatus appears in columns 6 to 9 in Table 1, and in graphic form in Figure 3 (left panel in top row).

From the direct experience obtained during our MMMM-experiment with an interferometer at rest, present writer may attest that without the "adjustments"

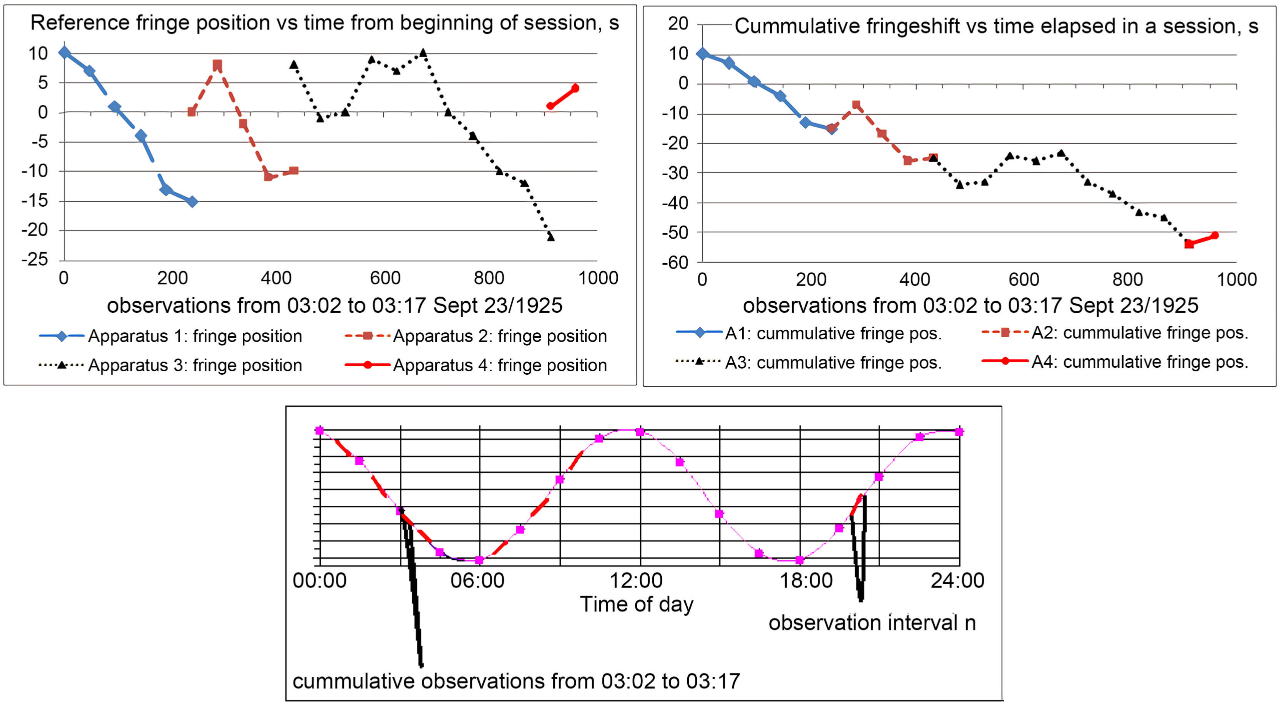

Figure 3. Reinterpretation of Miller's raw data as fringeshifts in an interferometer at rest at some well defined orientation. Top row: position of central black fringe on September 23/1925 at 03:17A.M. Vertical axis is in 0.1 fringe-widths. Horizontal axis shows elapsed time in seconds since beginning of the set of readings. Left graph shows individual readings for each apparatus (see text). Right graph shows the cummulative fringeshift that would be observed without "adjustments". Bottom row: qualitative graph of fringe position versus time of day in an interferometer at rest. Miller obtained N set of readings in a day (see text). Each 16-minute set of readings contributes a 16-minute interval (at the corresponding time of day) towards the 24-hr fringeshift curve.

the interference fringe pattern (which is the real object being observed shown in Miller's figure 7 ([13], p 211)) always keeps a steady drift, *i.e.*, without jumps. Evidently, discrete jumps are introduced by the "adjustments". Then, an approximate estimate for the readings to be observed without "adjustments" is provided by the cummulative fringeshifts registered by the four apparatuses, as shown in right panel, top row in **Figure 3**, where a steady non-random downward trend depicts the usual variations in experimental work.

Total fringeshift amounts to 6.1 fringe-widths during the 16 minute duration of this session, in Miller's interferometer with a 32 meter long optical path. In a smaller interferometer as the 2-meter long apparatus used in our MMMM-experiment, Miller's shift is equivalent to $6.1 \times 2/32 = 0.38$ fringe-widths. Such shift is visually observable and is consistent with our own experience in Bogota: "*During the setup process the first semester of* 2002, *we started with measurements every* 15 *minutes… The interference pattern from one observation to the next showed differences that could be appreciated by the naked eye*" ([15], p 80, column 2); similar remarks appear in another earlier paper ([10], p 198). This supports our contention that Miller's fringeshifts are (possibly to a large extent) due to true solar motion, rather than mere artifacts of "temperature drift".

During the Mount Wilson campaign, there were at least least two sets of readings per hour (see previous Section 2.4) over one working day, for a total of

N per day. Each set of readings provides an estimate for the response of the interferometer at rest during 16 minutes, at a given time of the day, as illustrated in the bottom part of **Figure 3**. The N sets of readings yield a first-order approximation to the response of Miller's interferometer in rest mode during one day.

An interested reader could easily carry out the whole exercise described in this subsection using Miller's original datasheets kept at the CWRU archive ([29], p 308).

3. Our 2002-2005 "Positive" Experiment with a Stationary Interferometer at CIF, Bogota

To begin with, let us state that in contrast to Michelson, Morley, Miller and almost every one else, present writer never mentions the words "ether", "ether wind" or "entrained ether" in the design and analysis of his interferometric data. On the contrary, all translational and rotational motions of earth and interferometer are referred to an inertial or preferred, strictly geometrical, frame Σ ("strictly" geometrical means without material or material-like properties).

Analysis in previous section of Michelson, MM and MMM-experiments suggests that the gathering of data in any interferometric experiment should be modified to insure that, instead of assuming that there is only a fraction of one-fringeshift from one reading to the next, the number of fringeshifts can be actually counted! To achieve this goal a slow rotation of the interferometer is required. The simplest, cheapest and most reliable slow rotation mechanism is the spinning Earth herself, so that we opted for an interferometer at rest relative to the ground floor laboratory at the International Center for Physics (CIF) in the National University Campus in Bogota (Colombia) [10] [15] [17] [18] [19] [20].

3.1. Conceptual Design of the MMMM-Experiment

The slow terrestrial rotation insures that in an interferometer with appropriate arm length the actual number of fringeshifts may be easily counted. The most important theoretical input for designing our experiment was the detailed calculation of expected fringeshifts in a stationary interferometer horizontally placed in a laboratory at a known longitude ϕ and latitude θ on a spinning Earth that tangentially moves in solar orbit at V_O = 29.8 km/s, while Sun moves with unknown velocity V_S relative to preferred frame Σ [14] [15], see **Figure 1**. Light propagates isotropically in Σ with constant speed c.

3.2. Details of the Design during 2002 of the MMMM-Experiment

Two lower rows in central panel of **Figure 2** show that long optical paths are not a necessity in the interferometer, thus avoiding (questionable and troublesome) multiple reflections, as in the 11 meter apparatus used in the 1887 MM-experiment. So, our apparatus had only one reflection at the end of each two-meter long arm—this is similar to Michelson's 1881 one-meter apparatus. Operational experience gathered by Michelson [2], MM [3], and Miller [13] suggests to avoid metal and wood components. Thus a setup similar to the MM-experiment was selected: a stationary (relative to the laboratory) interferometer was mounted directly upon a thirteen metric ton concrete block supported by a simple pneumatic system to decrease vibrations. Arm A1 was oriented towards local east and orthogonal arm (A2) towards local geographical north (*i.e.*, not towards the magnetic north).

Instead of white light as in MMM-experiment, we used monocromatic coherent laser light. During 2002 we tested two available laser sources (red and green), and selected the green one as the most reliable for our experiment.

The most important and hardest part of our design was to insure that we could actually measure magnitude of the expected fringeshift. As discussed in previous section, all classical experiments failed regarding this aspect.

At the beginning of 2002 we carried out several three-day long sessions, day and night, with a human observer permanently checking the pattern of interference-fringes appearing over a frost-glass screen. To decrease vibrations, this was done from Friday afternoon to Monday morning when the campus of National University is almost empty. The objective was to find the optimum time span between readings. For this the observer recorded the succession of positions and times (in hour, minutes and seconds) at which the observer could discern by the naked eye a motion towards left or right of a selected fringe. The same fringe was followed throughout the whole weekend session. It was found that the interference-pattern was quite stable, and that the eye could only distinguish changes in the position of the reference fringe at the scale of a few minutes, typically five to ten. To be on the safe side we chose to register the whole reference pattern every minute, leading to 1440 frames over a 24-hr rotation of the interferometer.

During 2002 Professor Manuel G. Forero and his Owaha group (Department of Systems Engineering, National University of Colombia) developed software to automatically store at every minute the image appearing in the video camera, and to convert the image into digital colour-level profiles, that were smoothed using Fourier transforms with a low pass filter.

3.3. Our High Orientational Resolution versus the Low Resolution in All MM-Type Experiments

Let us stress the most significant difference between our MMMM-experiment and all classical MM-type experiments: our high orientational resolution in the process of data gathering. Let us explain. Both in MM and in all Miller's experiments, data was collected when one of the arms was oriented to one of sixteen local directions: north, northeast, east, etc. That is, there was an angular distance of 22.5˚ between two consecutive readings. From the central panel in **Figure 2** it is evident that the expected fringeshift would be small (*i.e.*, less than one fringe-width) if the the speed of solar motion were slow, but the fringeshift would be large (*i.e.*, more than one fringe-width) if solar speed were around 200 km/s. Since current estimates of solar speed [5] [23] [24] [25] [26] are larger than 200 km/s the expected fringeshifts are certainly larger than one fringe-width when measurements are made every 22.5˚. Thus, the design of the MM-experiment was faulty from this contemporary view-point. Note that an angular step of 22.5˚ in a rotating interferometer is the same as taking a reading every 90 minutes in an interferometer at rest, as in our MMMM-experiment.

Instead, we used a video camera at rest in the laboratory to record every minute a photograph of the interference pattern. Thus our angular resolution is ninety times better than the 22.5˚ in MM [3], Miller [13] experiments, and in all classical MM-type experiments [9].

In other words, in a single 360˚ turn of our stationary interferometer lasting 24 hours we obtained 1440 readings (many more than in the whole 1887 MM-experiment). To attain the same angular resolution in any experiment using a rotating interferometer, measurements have to be made every 0.25˚ (=360˚/1440).

Our high angular resolution allowed us to follow the position of the very same fringe throughout the duration of a session, which sometimes lasted several weeks.

3.4. Results of Our 2003-2005 MMMM-Experiment

The MMMM-experiment itself ran over more than two years from January 2003 to February 2005, plus June 2005. Typically, there were several sessions each month, with the exception of May and June 2004 (when the video camera was stolen). Collected data [15] [17] [18] [19] [20] support our theoretical predictions. The raw data are stored in more than 300 flexible disks, which are available for any interested person to copy.

As usual in second-order experiments ([13], p 231, column 1), two velocities of sun relative to a preferred frame Σ were obtained from our data: 1) CIF-N in the northern galactic hemisphere: speed 365 km/s, $\alpha = 81˚$, $\delta = 79˚$ [19]. And, 2) CIF-S in the southern galactic hemisphere: speed 500 km/s, $\alpha = 250˚$, $\delta = -75˚$ [18]. Magnitude of our solar speeds is larger than Miller's, but it is in the same range of solar speeds reported in astronomy and astrophysics [5] [23] [24] [25] [26], although direction is not necessarily the same [32].

3.5. Compatibility of CIF-S Solar Velocity and the 2002 Experiment at Stanford University

With the objective of confirming once again the conventional "negative" interpretation of the MM-experiment, in 2002 a hightech experiment was carried out at Stanford University with a duration of several months [21]. Variations in the difference of frequency in two microwave cavities oriented along the local East-West and along the vertical direction were obtained at different times of day. Temperature of the cavities was controlled to an extremely high accuracy, within ±5 micro Kelvin. The experimenters observed unexpected periodical variations in the frequencies. The authors tried to find physical or astronomical explanations for such periodicity. Since no reasonable explanation was found, the observed periodical variations were dismissed as unexplained "*mechanical disturbances*", and were subtracted from the signal. The resulting white noise was interpreted as a new and more accurate confirmation of the conventional "null" interpretation of MM-type experiments.

In some senses, the Stanford setup is similar to a vertical interferometer with one arm parallel to the floor of the laboratory and the other arm perpendicular to the floor. The periodical structure of the unexplained "*mechanical disturbances*" is amazingly similar to the structure of the "positive" results obtained in our MMMM-experiment. This means that the raw data underlying Stanford's "*mechanical disturbances*" may have the same structure as the raw data underlying our MMMM-experiment at Bogota.

As a preliminary quantitative test we reported at PIRT-2017 [20] the correlation between the magnitude and direction of the "*mechanical disturbances*" observed in Palo Alto (California) on May 30/2002 and the magnitude and direction of terrestrial velocity on the floor of a laboratory located in Palo Alto the same day. Earth's motion was calculated with the solar velocity CIF-S reported in previous subsection. The unpublished graphs are included here as top row in Figure 4. Both correlations are extremely high: 0.998 for Earth's speed, and 0.991

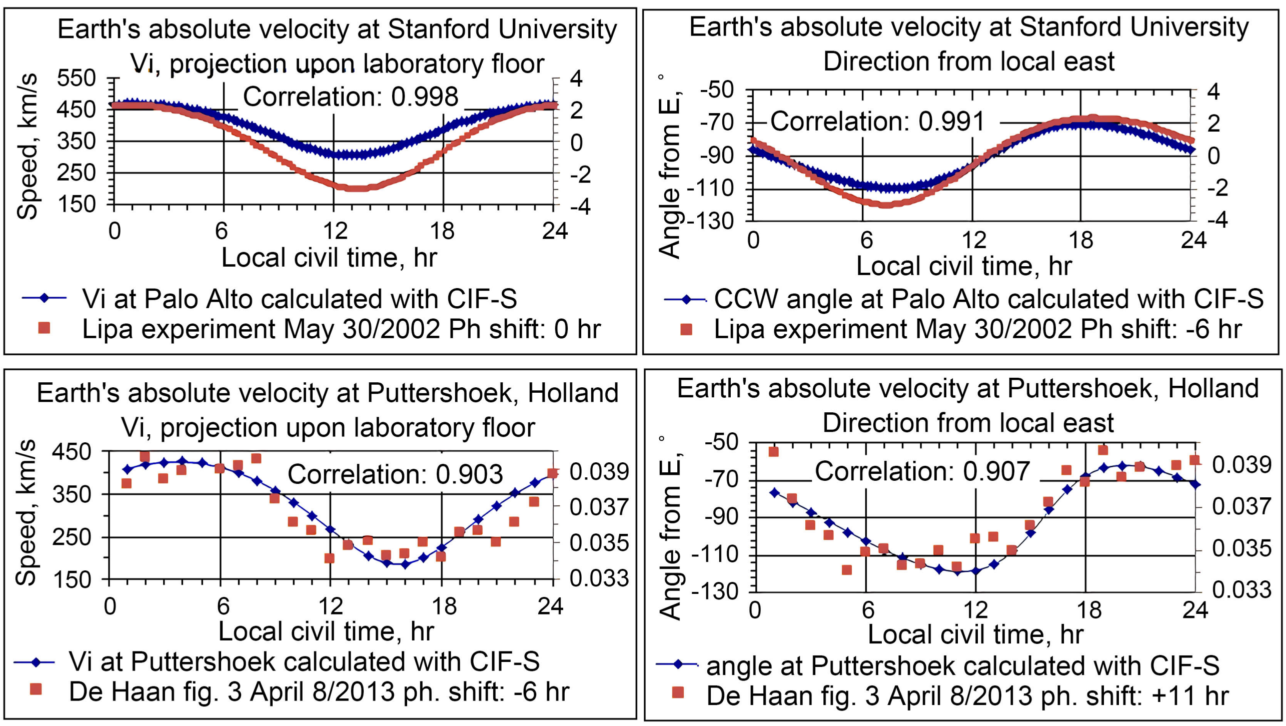

Figure 4. Modern interferometer-like experiments compared to absolute velocity of earth's center of mass calculated with our CIF-S absolute solar velocity. Top row: amplitude of unexplained "mechanical distrurbances" observed in 2002 at Stanford University [21] versus magnitude (correlation = 0.998) and direction (correlation = 0.991) of V_I (=projection of V_{CM} upon the floor of the laboratory). Bottom row: amplitude of signal observed in 2013 in Victor de Haan's Fabry-Perot cavity [22] versus magnitude (correlation = 0.903) and direction (correlation = 0.907) of V_I.

for direction of terrestrial velocity. The authors of the Stanford experiment may easily calculate correlations for other dates. Present writer is available for joint work.

3.6. Compatibility with 2012-2014 Experiments by Victor de Haan in the Netherlands

In his laboratory at Puttershoek, The Netherlands, in April 2012 Victor de Haan compared the phase of a standing wave to the phase difference in a Mach-Zehnder interferometer. Similar experiments were carried out from April/2013 to September/2014 involving Fabry-Perot cavities. De Haan found well-defined periodic responses in amplitude, and less-defined periodicities in azimuth [22]. Bottom row in **Figure 4** compares de Haan's amplitudes for April 8/2013 to magnitude (correlation 0.903) and direction (correlation 0.907) of terrestrial absolute velocity (calculated with CIF-S) projected onto the floor of the laboratory at Puttershoek. Similar correlations appear if terrestrial velocity is calculated with CIF-N. However, correlations with de Haan's azimuth are poor.

4. Closing Remarks: MM-Type Experiments Are Not Crucial

From our MMMM-experiment we obtained by optical means, for the first time ever in a closed laboratory, quantitative estimates for the value of solar velocity relative to a preferred frame. This success contradicts Poincaré's principle stating the impossibility of measuring absolute motion in a closed laboratory. We succeeded, without additional ad hoc assumptions, where Michelson, Morley, Miller and many others failed: we witnessed the slow drift of the reference fringe during the slow terrestrial rotation of our interferometer, and counted the net number of fringe-widths as the reference fringe drifted back and forth.

Given the "positive" results of the MMMM-experiment [15] [17] [18] [19] [20], this writer considers that the notion of a preferred frame of reference Σ should be re-instated [32]. This notion is equivalent to Newton's absolute space, operationally identified by him as a frame at rest relative to the fixed stars. Of course, existence of Σ is compatible with the currently accepted anisotropy of the CMB radiation as observed from the moving Earth.

By the same token, all "negative" experiments, say the Stanford experiment [21], claim that they obtained confirmation of Lorentz-invariance to a high accuracy. The foundational basis of the theory for such experiments was only recently completed by Sfarti who analysed the effect of rotation of earth upon an interferometer on its surface in tangential motion relative to an inertial frame: "*We present the derivation of the Sagnac, Michelson-Morley, Kennedy-Thorndike and the Hammar experiments as viewed from the Earth-bound uniformly rotating frame, that is, the frame of the laboratory where the experiment is taking place. To our best knowledge such an attempt has never been made before, possibly due to its mathematical difficulty, so no precedents exist, this is a first*", underlinings added ([30], p 1). By the way, twenty years ago present writer published a similar analysis in a pre-relativistic context [14]—work inspired by Miller [13] and Nassau and Morse [16].

So, proponents of "positive" experiments claim that observation supports their hypothesis that solar velocity can be measured with an interferometer. Likewise, supporters of "negative" experiments claim that similar observations support their hypotesis of Lorentz-contraction. Can these two (apparently) contradictory statements be both true?

Our answer is positive. Furthermore, the reason is simple, and is implicit in the distinction made in Section 1 between "positive" and "negative" experiments. In both cases the object under observation is the same: an interference pattern. However, the "thing" being observed is (in general) different. "Positive" experiments focus on the complete fringeshift of a reference fringe, while "negative" experiments only focus on the fractional component of the said fringeshift. In the case of very small interferometers there is no difference between the two cases.

However, in all cases the end products from "positive" and "negative" experiments are different: a value for solar velocity in "positive" experiments, and a support for Lorentz-contraction in "negative" experiments.

From a pragmatical view point: that's it. Both experiments are correct within their bounds. Correlations in **Figure 4** are to be expected because the physical object (*i.e.*, the interference pattern) being observed in both cases is the same. The difference is in the data recording and reduction.

The difficulty arises when interpetations outside the scope of the tested hypothesis are offered. For instance, the "negative" experiment was not designed to test the hypothesis that "absolute motion does not exist", or to test the hypothesis that "a preferred frame does not exist".

In plain words, we may say that "positive" and "negative" experiments cannot distinguish between pre-relativistic and relativistic theories. This runs contrary to many beliefs! In some sense, we have wasted our time for more than a century...Just sterile discussion! A dialogue between deaf people!

Nonetheless, there are deeper, and related among them, questions that were not addressed, let alone tested, in the "positive" and "negative" experiments: what is the nature of light? How does light propagate? How is light connected to electromagnetic force? What is the origin of electromagnetic force? What is the origin of other fundamental forces? How do fundamental forces propagate?

Ether may be a possible common component in the answer to all previous questions. Such a subject is beyond the scope of present paper, and it is not further considered here. However, let us mention that if ether exists, it has to exist somewhere, for instance it may populate the geometrical space called "preferred frame".

Beyond the "positive" and "negative" experiments, there are arguments of a different class that calls for the existence of a preferred frame. Two conservation principles of classical physics (energy and linear momentum) implicitly require a preferred frame to define the meaning of the speed that is conserved. Let me ask, if there is no preferred frame, what is the value of the speed that is conserved when Einstein and a Maxwell demon are together in a vehicle comoving with a light ray?

To end, let us mention that present writer has also worked during the last thirty years on a unified theory of nature that may fulfill Einstein's dream, see [33] and references therein. In that context there are Q-solutions to the classical wave equation that are isomorph under all relativistic transformations (Lorentz, Poincaré, Einstein) and under the pre-relativistic Doppler-Voigt [34] transformation. They constitute the new group of D'Alembertian isomorph transformations [33] and page 111 in [35]. In that context the apparently contradictory outcomes of both the "positive" and "negative" experiments are to be expected. Thus, the paradoxical results discussed here constitute observational evidence supporting the existence of the theoretically predicted Q-functions. After all, our MMMM-experiment was not a waste of time! This subject is developed elsewhere.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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