MICHELSON-MORLEY EXPERIMENTS REVISITED and the COSMIC BACKGROUND RADIATION PREFERRED FRAME

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Abstract

We report a simple re-analysis of the old results from the Michelson-Morley interferometer experiments that were designed to detect absolute motion. We build upon a recent (1998) analysis of the original data by Múnera, which revealed small but significant effects after allowing for several systematic errors in the original analysis. The further re-analysis here reveals that a genuine effect of absolute motion is expected, in what is essentially a quantum interference experiment, but only if the photons travel in the interferometer at speeds $V < c$. This is the case if the interferometer operates in a dielectric, such as air, or helium as was the case of the Illingworth (1927) Michelson-Morley experiment. The re-analysis here of the Illingworth experimental data, after correcting for the refractive index effect of the helium, reveals an absolute speed of the Earth of $v = 369 \pm 123$ km/s, while the Miller experiment (1933), after correcting for the refractive index effect of the air, now gives a speed of $v = 335 \pm 57$km/s, which are in agreement with the speed of $v = 365 \pm 18$ km/s determined from the dipole fit, in 1991, to the NASA COBE satellite Cosmic Background Radiation (CBR) observations. These experimental results refute Einstein's assertion that absolute motion through space has no meaning, and require a re-assessment of the interpretation of Special and General Relativity. This re-analysis was motivated by developments in a new information-theoretic modelling of reality, known as Process Physics[1]

Key words: Michelson-Morley interferometer, Cosmic Background Radiation (CBR), COBE, preferred frame, quantum foam, quantum gravity, process physics.

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[1]**Process Physics** Web Page: http://www.socpes.flinders.edu.au/people/rcahill/processphysics.html

One fundamental assumption in physics is that the Michelson interferometer laboratory experiment of 1881 [1], and repeated by Michelson and Morley in 1987 [2], by Miller in 1925 and 1933 [3, 4], and by Illingworth in 1927 [5], that were designed to detect absolute motion, gave a null result, vindicating Einstein's assumption that absolute motion (motion relative to space itself) has no meaning; it is *in principle* not detectable in a laboratory situation. Motion of objects is always relative to other objects, according to Einstein. Using this assumption Einstein went on to construct the Special and General Theory of Relativity, which uses the notion of spacetime to avoid any notion of absolute space. Of course Einstein's formalism has been abundantly confirmed both by the extensive use of the special theory in particle physics experiments and theory, and by the general theory in various experimental and observational situations.

Nevertheless we report here experimental evidence that absolute motion is detectable in laboratory experiments, such as those done by Michelson and Morley and the others, but that this requires a re-analysis of the operation of their interferometer, as reported herein. This analysis leads to a speed which agrees with that found from the NASA COBE satellite observations on analysing the dipole anisotropy of the Cosmic Background Radiation. Together these results show that absolute motion has been detected. New interferometer experiments are needed to confirm that the direction of that motion is the same as the direction discovered by the COBE mission. These results are profoundly significant to our understanding of reality. It follows from recent work that these experimental outcomes will not be in conflict with the Einstein phenomenology, but require a major re-assessment of what that phenomenology describes [6].

Recent developments in the new information-theoretic modelling of reality, known as *Process Physics* [6, 7], indicate that the Einstein Special and General Relativity formalisms arise as a consequence of an emergent quantum-foam explanation for space, but with this quantum foam amounting to an absolute and preferred frame of reference, in what is a unified quantum theory of space, gravity and matter. In [6] it was shown how the general theory account of gravity arises from an amalgam of two distinct quantum foam effects, one being the effective diffusion of the quantum foam towards 'matter' that acts as a 'sink', together with the classical measurement protocol based on the apparent invariance of the speed of light, which uses the radar method to retrospectively assign spacetime coordinates to distant events, that is, spacetime is in fact a historical record of reality, and not reality itself. Here the invariance of the speed of light is caused by the genuine dynamical effect of the quantum foam on moving rods and clocks, as suggested long ago by Fitzgerald and Lorentz to explain the, here now disputed, null result of the Michelson-Morley experiment. Observers adopting this phenomenological property of light within the classical measurement protocol will find, according to Process Physics, that the formalism of the General Theory of Relativity describes their historical records which have the form of a spacetime geometrical construct, but that this spacetime construct has no ontological significance. In this construct the modelling of time by geometry is entirely appropriate; it is essentially a pagination of the historical record. The resolution of the confusion between the geometrical modelling of time in historical records and time as an actual process has now been achieved within the new *Process Physics*. The older but still current *Non-Process Physics* modelling of reality, which has been with us since Galileo and Newton introduced the geometrical modelling of time, is now superseded.

An implication of these developments in *Process Physics* is that it should be possible *in principle* to overcome the classical measurement protocol effects by using the long-known nonlocality of quantum processes which should be sensitive to absolute motion through this quantum foam. Indeed ever since the Aspect [8] experiment showed a violation of the Bell inequalities, in the context of the Einstein-Podolsky-Rosen (EPR) nonlocal effects it has been understood that quantum collapse events caused by quantum detectors appear to require a preferred frame, and so appear to be in conflict with Einstein's assumption. The work of Hardy [9] and Percival [10] suggested that 'double-EPR' experiments could reveal an absolute frame, and hence absolute motion, though such experiments for this purpose would be extremely difficult. However the old Michelson-Morley interferometer experiment is actually a quantum interferometer, that is, in principle it could be done with one photon at a time, and we inquired why it is believed that it was unable to detect a preferred frame, and so absolute motion. In fact it can do so.

As described in Fig.1 the beamsplitter/mirror A sends a photon $\psi(t)$ into a superposition $\psi(t) = \psi_1(t) + \psi_2(t)$, with each component travelling in different arms of the interferometer, until they are recombined in the quantum detector which results in a localisation process, and one spot in the detector is produced. Repeating with many photons, reveals that the interference between ψ_1 and ψ_2 at the detector results in fringes. Before the quantum theory (and in particular before the new quantum foam physics) Michelson designed the interferometer with the idea that any motion through absolute space (then called the luminiferous aether) would result in different path lengths for light waves in the two arms, which would show as a shift in the fringe. Of course as an experimental expediency one rotates the apparatus through 90^o so that the roles of the two arms are interchanged, this rotation then should result in a shift of the fringes, which is an effect more easily observed. However Michelson and Morley reported a null result, despite a small effect actually being seen. Fitzgerald and then Lorentz then offered an explanation for the null result, namely that the failure to get an effect was caused by the actual contraction of the arm moving lengthwise through the absolute space, as we show below. However long ago it was decided by physicists that the more elaborate Einstein explanation in terms of spacetime transformations was superior to this dynamical explanation.

In reviewing the operation of the Michelson-Morley interferometer (see below) it was noticed that the Fitzgerald-Lorentz contraction explanation only implies a null effect if the experiment is performed in vacuum. In air, in which photons travel slightly slower than in vacuum, there should be a small fringe shift effect when the apparatus is rotated, even after taking account of the Fitzgerald-Lorentz contraction. This appears to have gone unnoticed. As well Múnera [11] in 1998 has corrected the original results for various systematic errors, and shown that these interferometer experiments do indeed reveal small but significant non-null results, but as expected now, only when they are operated in a dielectric.

We have applied the elementary correction required for the effects of the air, or in one case helium, to various interferometer results as corrected by Múnera for other systematic errors. The correction is in fact large, being some two orders of magnitude when applied to the Illingworth experimental data, and the new analysis here results in a speed of $v = 369 \pm 123$ km/s. Re-analysis of the Miller experiment (1933), after correcting for the refractive index effect of the air, now gives a speed of $v = 335 \pm 57$km/s. These are to be compared with the speed of $v = 365 \pm 18$ km/s determined from the dipole fit, in 1991, to the NASA COBE satellite Cosmic Background Radiation observations [12].

We now indicate the proper understanding of the operation of the Michelson-Morley interferometers when operated in a dielectric, and then report the corrected results, as shown in Fig.2. The two arms are constructed to have the same lengths when they are physically parallel to each other. For convenience assume that the value L of this length refers to the lengths when at rest in the quantum foam. The Fitzgerald-Lorentz effect is that the arm AB parallel to the direction of motion is shortened to

$$L_{\parallel} = L\sqrt{1 - \frac{v^2}{c^2}} \tag{1}$$

by motion through the quantum foam.

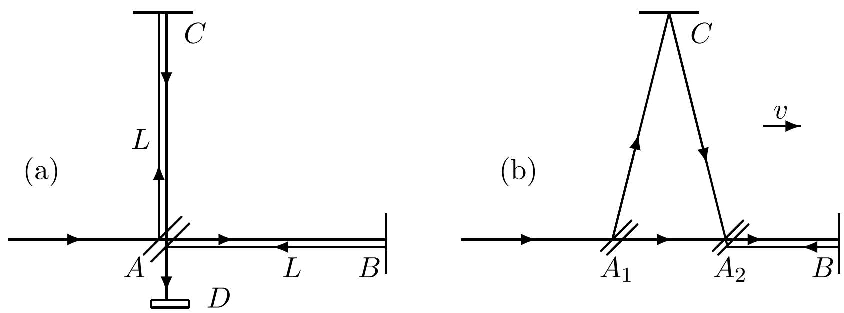

Figure 1: Schematic diagrams of the Michelson Interferometer, with beamsplitter/mirror at A and mirrors at B and C, on equal length arms when parallel, from A. D is a quantum detector (not drawn in (b)) that causes localisation of the photon state by a collapse process. In (a) the interferometer is at rest in the quantum foam. In (b) the interferometer is moving with speed v relative to the quantum foam in the direction indicated. Interference fringes are observed at the quantum detector D. If the interferometer is rotated in the plane through 90^o, the roles of arms AC and AB are interchanged, and during the rotation shifts of the fringes are seen in the case of absolute motion, but only if the apparatus operates in a dielectric. By counting fringe changes the speed v may be determined.

Following Fig.(1), we consider the case when the apparatus is moving at speed v through the quantum foam, and that the photon states travel at speed $V = c/n$ relative to the quantum foam, where n is the refractive index of the gas and c is the speed of light, in vacuum, relative to the quantum foam. Let the time taken for ψ_1 to travel from $A \to B$ be t_{AB} and that from $B \to A$ be t_{BA}. In moving from the beamsplitter at A to B, the photon state ψ_1 must travel an extra distance because the mirror B travels a distance vt_{AB} in this time, thus the total distance that must be traversed is

$$Vt_{AB} = L_{\parallel} + vt_{AB}. \tag{2}$$

Similarly, on returning from B to A, the photon state ψ_1 must travel the distance

$$Vt_{BA} = L_{\parallel} - vt_{BA}. \tag{3}$$

Hence the total time t_{ABA} taken for ψ_1 to travel from $A \to B \to A$ is given by

$$\begin{aligned} t_{ABA} = t_{AB} + t_{BA} &= \frac{L_{\parallel}}{V-v} + \frac{L_{\parallel}}{V+v} &(4)\\ &= \frac{L_{\parallel}(V+v) + L_{\parallel}(V-v)}{V^2 - v^2} &(5)\\ &= \frac{2LV\sqrt{1 - \frac{v^2}{c^2}}}{V^2 - v^2}. &(6) \end{aligned}$$

Now, assuming that the time taken for the photon state ψ_2 to travel from $A \rightarrow C$ is t_{AC}, but that the apparatus travels a distance vt_{AC} in that time, we can use the Pythagoras theorem:

$$(Vt_{AC})^2 = L^2 + (vt_{AC})^2 \tag{7}$$

which gives

$$t_{AC} = \frac{L}{\sqrt{V^2 - v^2}}, \tag{8}$$

and including the return trip ($C \rightarrow A, t_{CA} = t_{AC}, t_{ACA} = t_{AC} + t_{CA}$) results in

$$t_{ACA} = \frac{2L}{\sqrt{V^2 - v^2}}, \tag{9}$$

giving finally for the time difference for the two arms

$$\Delta t = \frac{2LV\sqrt{1 - \frac{v^2}{c^2}}}{V^2 - v^2} - \frac{2L}{\sqrt{V^2 - v^2}}. \tag{10}$$

Now trivially $\Delta t = 0$ if $v = 0$, but also $\Delta t = 0$ when $v \neq 0$ but only if $V = c$. This then would result in a null result on rotating the apparatus. Hence the null result of the Michelson-Morley apparatus is only for the special case of photons travelling in vacuum for which $V = c$, as confirmed by the modern vacuum interferometer experiment of Brillet and Hall [13], which in-effect confirms (1). However if the apparatus is immersed in a gas then $V < c$ and a non-null effect is expected on rotating the apparatus, since now $\Delta t \neq 0$. It is essential then in analysing data to correct for this refractive index effect. Putting $V = c/n$ in (10) we find, for $v << V$ and when $n \approx 1^+$, that

$$\Delta t = L(n^2 - 1)\frac{v^2}{c^3} + ... \tag{11}$$

However if the data is analysed not using the Fitzgerald-Lorentz contraction (1), then, as done in the old analyses, the estimated time difference is

$$\Delta t = \frac{2LV}{V^2 - v^2} - \frac{2L}{\sqrt{V^2 - v^2}}, \tag{12}$$

which again for $v << V$ and $n \approx 1^+$, gives

$$\Delta t = Ln^3\frac{v^2}{c^3} + ... \approx L\frac{v^2}{c^3} \tag{13}$$

The value of Δt is deduced from analysing the fringe shifts, and then the speed v_{MM} (in previous Michelson-Morley analyses) has been extracted using (13), instead of the correct form (11). Δt is typically of order $10^{-15}s$. However it is very easy to correct for this oversight. From (11) and (13) we obtain, for the corrected absolute speed through the quantum-foam v_{QF},

$$v_{QF} = \frac{v_{MM}}{\sqrt{n^2 - 1}}. \tag{14}$$

Note that for air at STP $n = 1.00029$, while for helium at STP $n = 1.000036$, and so the correction factor of $1/\sqrt{n^2 - 1}$ is large. The corrected speeds v_{QF} for four MM experiments are shown in Fig.2, and compared with the CBR speed determined from the COBE data [12].

Múnera [11] has reviewed these interferometer experiments and uncovered systematic errors and as well applied standard statistical tests to the values originally reported. He has noted that the Michelson-Morley experiments and subsequent repetitions never were null, and that correcting for invalid inter-session averaging leads to even larger non null results. Múnera's new results are as follows. The original Michelson-Morley data [2] now gives $v_{MM} = 6.22$km/s with a standard deviation on the mean of 0.93km/s for one set of noon sessions, while giving $v_{MM} = 6.80$km/s with a standard deviation on the mean of 2.49km/s for 18^h observations. For Miller [3, 4], from results at Mt Wilson after moving the Morley-Miller [14] experiment, the new result is $v_{MM} = 8.22$km/s with an upperbound at 95% CL of $v_{MM} = 9.61$km/s and a lower bound at 95% CL of $v_{MM} = 6.83$km/s. The Illingworth [5] data (from a helium-filled inteferometer) gives smaller values of $v_{MM} = 3.13$km/s with an upperbound at 95% CL of $v_{MM} = 4.17$km/s and a lower bound at 95% CL of $v_{MM} = 2.09$km/s.

Hence the Michelson-Morley and Miller values for v_{MM} appear to differ significantly from the value from Illingworth. But this is now an expected outcome as Illingworth used helium (to control temperature variations) instead of air. Because of the different refractive indices of air and helium the correction factors are substantially different, and as shown in Fig.2 the air and helium filled interferometers now give comparable results, when corrected. We have assumed that Illingworth used helium at STP. We have also used the n value for air at STP in correcting the Miller results even though the experiments were performed at altitude on Mt. Wilson.

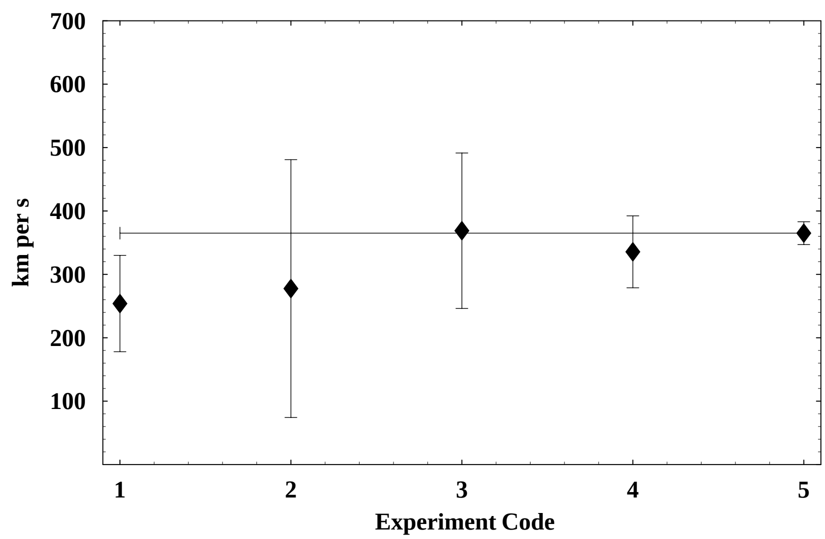

Figure 2: Speeds v_{QF} in km/s determined from various Michelson-Morley experiments (**1**)-(**4**) and COBE (**5**): (**1**) Michelson-Morley (noon observations) [2], (**2**) Michelson-Morley (18^h observations) [2], (**3**) Illingworth [5], (**4**) Miller, Mt. Wilson [4], and finally in (**5**) the speed from the COBE satellite observation of the CBR microwave spectrum dipole term [12]. The results (**1**)-(**4**) are not corrected for the ±30km/s of the orbital motion of the earth about the sum, though this correction was made, as well as that for the satellite orbital speed, in the case of (**5**). The horizontal line at $v = 365$km/s is to aid comparisons with the COBE data.

Of course the vacuum experiment by Brillet and Hall [13] gave a genuine null outcome as now expected. The presence of gases in these early experiments, rather than high vacuum, was of course an experimental expediency, but only because of this can we now realise the full implications of these long forgotten experiments.

Hence the old interferometer data is not only non-null but the extracted speeds agree, within errors, with the speed determined from analysis of the CBR dipole component observed by the COBE mission. These results demonstrate that absolute motion has a meaning and is measureable.

A new class of experiment can now be carried out using say a rotateable fibreoptic laser-based systems, and such quantum-gravity experiments are capable of measuring the absolute speed and direction of motion of the Earth through the quantum foam that is space. As well the very large gravity-wave laser interferometers could be used in a gas-filled mode rather than a vacuum mode and, if sufficient temperature control can be achieved, they could be used as absolute motion detectors. Daily and seasonal changes in v_{QF} will be seen as $\vec{v}_{QF}$ is the vector sum of various contributions due to the effects of the dissipative and non-uniform flows of the quantum foam (which is gravity, [6]) by the earth, moon and sun, as well as the overall effect of the motion of the Earth and the solar system through the CBR determined quantum-foam frame of reference which is, it now turns out, was one of the main discoveries of the COBE mission. The good agreement here between the speeds from interferometers and COBE implies that the CBR preferred frame is the actual physical frame of the universe.

A task for new interferometers would be to establish the in-ward flow rate of the quantum foam, predicted to be 11.2km/s at the Earth's surface (from $v = \sqrt{2GM/R}$, see [6]). This quantum-foam flow is a key test of the quantum theory of gravity that has emerged from *Process Physics* [6, 7, 15, 16, 17, 18], and in which Newton's gravitational constant G is a measure of the rate at which 'quantum matter' dissipates quantum foam.

The significance of this new interpretation of the outcomes of the various Michelson-Morley experiments can hardly be overstated, it will change forever how physicists comprehend reality. These results undermine Einstein's assertion that absolute motion has no meaning. The *Process Physics* supersedes the prevailing *Non-Process Physics* modelling of reality, which is characterised by the geometrical modelling of time. It is remarkable that these experiments were carried out with such diligence and care so long ago that their data, when now properly analysed, yield speeds consistent with those found from satellite technology 104 years later, and even more so when we understand that some of the experimenters themselves believed they had failed to detect non-null effects. In effect the Michelson interferometer, operating with dielectric medium, is a quantum interferometer that performed the first quantum gravity experiment as it was capable of detecting absolute motion through the quantum foam that is space.

The re-analysis here of the various experimental data clearly implies that a major re-interpretation of the the Special and General Relativity formalism is necessary, but such an re-interpretation has already emerged from *Process Physics* [6]: it amounts to changing the measurement protocol used by observers in recording distant events. A consequence of this is that one of the possible 'frames of reference' is actually the real physical frame, since motion of the observer relative to that frame is measureable by the observer.

This paper is a revised version of [19], and we thank Vladimir Hnizdo for drawing to our attention an error in [19]. As well the data in Fig.2 is now shown in chronological order.

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