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Analysis of Data from a Quantum Gravity Experiment

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Abstract

A new information-theoretic modelling of reality has given rise to a quantum-foam description of space, relative to which absolute motion is meaningful. In a previous paper (Cahill and Kitto) it was shown that in this new physics Michelson interferometers show absolute motion effects when operated in dielectric mode, as indeed all such experiments had indicated, and re-analysis of the experimental data showed that the measured speeds were all in agreement with the COBE CBR dipole-fit speed of 365 ± 18km/s. Here the new physics is applied, using a different type of analysis, to the extensive data from dielectric-mode interferometer observations by Miller (1933). Here the speed of in-flow of the quantum foam towards the Sun is determined from Miller's data to be 47 ± 6km/s, compared to the theoretical value of 42km/s. This observed in-flow is a signature of a quantum gravity effect in the new physics.

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A new information-theoretic modelling of reality [1, 2] has given rise to a quantum-foam description of space, relative to which absolute motion is meaningful. In Ref.[3] it was shown that in this new physics Michelson interferometers [4] show absolute motion effects when operated in dielectric mode, as indeed all such experiments had in fact indicated, and re-analysis of the experimental data showed that the measured speeds were all in agreement with each other and together in agreement with the COBE CBR dipole-fit speed of 365±18km/s [5] using the Múnera [6] re-analysis of interferometer data. The new physics is here further tested against experiment by re-analysing the extensive dielectric-mode interferometer data of Miller [7] and extracting a quantum-gravity effect. These results amount to a dramatic development in fundamental physics.

Although the theory and experiment together indicate that absolute motion is an aspect of reality one must hasten to note that this theory also implies that the Einstein Special and General Theory of Relativity formalism remains essentially intact. In [1] it was shown that this formalism arises from the quantum-foam physics, but that the quantum-foam system amounts to a physically real foliation of the spacetime construct. Despite this there are some phenomena which are outside the Einstein formalism, namely the detection of absolute motion. We see here the emergence of a new theoretical system which subsumes the older theory and covers new phenomena, in particular it unifies gravity and the quantum phenomena.

As shown in [3] and reviewed here the new physics provides a different account of the Michelson interferometers. The main outcome is that the time difference for light travelling via the orthogonal arms, when one arm is parallel to the direction of motion, is now given by

$$\Delta t = k^2 \frac{Lv^2}{c^3}. \tag{1}$$

Here v is the magnitude of the absolute velocity $\mathbf{v}$ of the interferometer through the quantum-foam, projected onto the plane of the interferometer. And $k = \sqrt{n(n^2-1)}$ where n is the refractive index of the medium through which the light in the interferometer passes, L is the length of each arm and c is the speed of light relative to the quantum foam. This expression follows from both the Fitzgerald-Lorentz contraction effect and that the speed of light through the dielectric is $V = c/n$, ignoring any Fresnel dragging effects. This is one of the aspects of the quantum foam physics that distinguishes it from the Einstein formalism and is discussed in [3]. The time difference Δt is revealed by the fringe shifts on rotating the interferometer. In Newtonian physics $k = \sqrt{n^3}$ [3, 4], while in Einsteinian physics $k = 0$ expressing the fundamental assumption that absolute motion is not measurable and indeed has no meaning. So the experimentally determined value of k is a key test of fundamental physics.

In deriving (1) in the new physics it is essential to note that space is a quantum-foam system [1, 2] which exhibits various subtle features. In particular it exhibits real dynamical effects on clocks and rods. In this physics the speed of light is only c relative to the quantum-foam, but to observers moving with respect to this quantum-foam the speed appears to be still c, but only because their clocks and rods are affected by the quantum-foam. As shown in [1] such observers will find that observations of distant events will be described by the Einstein spacetime formalism, but only if they restrict measurements to those achieved by using clocks, rods and light pulses. It is simplest in the new physics to work in the quantum-foam frame of reference. If there is a dielectric present at rest in this frame, such as air, then the speed of light in this frame is $V = c/n$. If the dielectric is moving with respect to the quantum foam, as in an interferometer attached to the Earth, then the speed of light relative to the quantum-foam is still $V = c/n$ up to corrections due to Fresnel drag. But this dragging is a very small effect and is not required in the present analysis. Hence this new physics requires a different method of analysis from that of the Einstein physics. With these cautions we now describe the operation of a Michelson interferometer in this new physics, and show that it makes predictions different to that of the Einstein physics. Of course experimental evidence is the final arbiter in this conflict of theories.

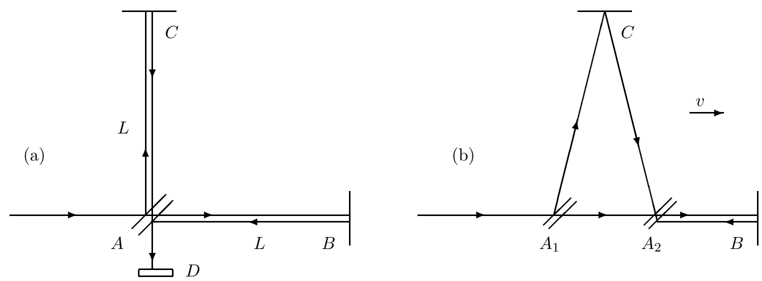

Figure 1: Schematic diagrams of the Michelson Interferometer, with beamsplitter/mirror at A and mirrors at B and C, on equal length arms when parallel, from A. D is a quantum detector (not drawn in (b)) that causes localisation of the photon state by a collapse process. In (a) the interferometer is at rest in space. In (b) the interferometer is moving with speed v relative to space 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.

As shown 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 (D) 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. To simplify the analysis here assume that the two arms are constructed to have the same lengths when they are physically parallel to each other. The Fitzgerald-Lorentz effect in the new physics is that the arm AB parallel to the direction of motion is shortened to

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

by motion through space at speed v. Following Fig.(1) we consider the case when the apparatus is moving at speed v through space, and that the photon states travel at speed $V = c/n$ relative to the quantum-foam which is space, where n is the refractive index of the gas and c is the speed of light, in vacuum, relative to the space. Let the time taken for ψ_1 to travel from $A \rightarrow B$ be t_{AB} and that from $B \rightarrow A$ 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

$$Vt_{AB} = L_{\parallel} + vt_{AB}. \tag{3}$$

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

$$Vt_{BA} = L_{\parallel} - vt_{BA}. \tag{4}$$

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

$$t_{ABA} = t_{AB} + t_{BA} \quad = \quad \frac{L_{\parallel}}{V - v} + \frac{L_{\parallel}}{V + v} \tag{5}$$

$$= \frac{L_{\|}(V+v)+L_{\|}(V-v)}{V^2-v^2} \tag{6}$$

$$= \frac{2LV\sqrt{1-\frac{v^2}{c^2}}}{V^2-v^2}. \tag{7}$$

Now let the time taken for the photon state ψ_2 to travel from $A \to C$ be t_{AC}, but in that time the apparatus travels a distance vt_{AC}. Pythagoras' theorem then gives

$$(Vt_{AC})^2 = L^2 + (vt_{AC})^2 \tag{8}$$

which gives

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

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

$$t_{ACA} = \frac{2L}{\sqrt{V^2-v^2}}, \tag{10}$$

giving finally for the time difference for the two arms

$$\Delta t = \frac{2LV\sqrt{1-\frac{v^2}{c^2}}}{V^2-v^2} - \frac{2L}{\sqrt{V^2-v^2}}. \tag{11}$$

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 in the new physics is only for the special case of photons travelling in vacuum for which $V = c$. However if the Michelson-Morley apparatus is immersed, for example, 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 (11) we find for $v << V$ that

$$\Delta t = Ln(n^2-1)\frac{v^2}{c^3} + \mathrm{O}(v^4), \tag{12}$$

that is $k = \sqrt{n(n^2-1)}$, which gives $k = 0$ for vacuum experiments ($n = 1$).

However if the data from dielectric mode interferometers is (incorrectly) analysed not using the Fitzgerald-Lorentz contraction (2), then, as done in the old analyses, the estimated Newtonian-physics time difference is

$$\Delta t = \frac{2LV}{V^2-v^2} - \frac{2L}{\sqrt{V^2-v^2}}, \tag{13}$$

which again for $v << V$ gives

$$\Delta t = Ln^3\frac{v^2}{c^3} + \mathrm{O}(v^4), \tag{14}$$

that is $k = \sqrt{n^3}$. The value of Δt is deduced from analysing the fringe shifts, and then the speed v_M (in previous Michelson-Morley type analyses) has been extracted using (14), instead of the correct form (12). Δt is typically of order $10^{-15}s$ in gas-mode interferometers, corresponding to a fractional fringe shift. However it is very easy to correct for this oversight. From (12) and (14) we obtain, for the corrected absolute speed v through space, and for $n \approx 1^+$,

$$v = \frac{v_M}{\sqrt{n^2 - 1}}. \tag{15}$$

Of the early interferometer experiments Michelson and Morley [8] and Miller [7] operated in air ($n = 1.00029$), while that of Illingworth [9] used Helium ($n = 1.000035$). We expect then that for air interferometers $k^2_{air} = 0.00058$ (i.e. $k_{air} = 0.0241$) and for Helium $k^2_{He} = 0.00007$, which explains why these experiments reported very small but nevertheless non-null and so significant effects. All non-vacuum experiments gave $k > 0$, that is, a non-null effect. All vacuum ($n = 1$) interferometer experiments, having $k = 0$, give null effects as expected, but such experiments cannot distinguish between the new physics and the Einstein physics, only dielectric-mode interferometers can do that. The notion that the Michelson-Morley experiment gave a null effect is a common misunderstanding that has dominated physics for more than a century. By "null effect" they meant that the effect was much smaller than expected, and the cause for this is only now apparent from the above. When the air and Helium interferometer data were re-analysed using the appropriate k values in [3] they gave consistent values which were also in agreement with the CBR speed. So these early interferometer experiments did indeed reveal absolute motion, and demonstrated that $k \neq 0$ in these experiments.

Here the data from the exquisite and extensive air-interferometer experiments with $L = 64$m (obtained by multiple reflections along the arms) by Miller at Mt.Wilson (Latitude $+34^0 13'$) beginning in 1921 [7] are re-analysed using not only the quantum-foam effect in (1), but also a quantum-gravity effect predicted by the new physics. It turns out that Miller actually performed the first quantum gravity experiment. Miller reported in [7] particular observations over four days in 1925/26 recording the time variation of the projection of the velocity $\mathbf{v}$ onto the interferometer throughout each of these days. His data is shown in Fig.2 for the azimuths and v_M speeds obtained from fringe shifts. The azimuth is the angle measured from the local meridian indicating the direction of the projected velocity $\mathbf{v}$, and the v_M speed is defined as that from (1) with $k = 1$ using the measured Δt, so that $v = v_M/k$.

Miller's idea was that $\mathbf{v}$ should have two components: (i) a cosmic velocity of the solar system through space, and (ii) the orbital velocity of the Earth about the Sun through space. Over a year this vector sum would result in a changing $\mathbf{v}$, as was in fact observed, and is obvious in Fig.2. Further, since the orbital speed was known, Miller was able to extract from the data the magnitude and direction of $\mathbf{v}$ as the orbital speed offered an absolute scale. We shall use $\overline{k}$ as the k value obtained by this approach. Miller was led to the conclusion that for reasons unknown the interferometer did not indicate true values of v, and for this reason he introduced the parameter $\overline{k}$. Miller noted, in fact, that $\overline{k}^2 << 1$. Fitting the data using $v_{tangent} = 30$km/s we obtain $\overline{k} = 0.044 \pm 0.005$ (Miller found $\overline{k} = 0.046$) and $v = 210$km/s and a direction (see later). However that $\overline{k} > k_{air}$ tells us that another velocity component has been overlooked. Miller only knew of the tangential or orbital speed of the Earth, whereas the new physics predicts that as-well there is a quantum-gravity radial in-flow $\mathbf{v}_{in}$ of the quantum foam, so

$$\mathbf{v} = \mathbf{v}_{cosmic} + \mathbf{v}_{tangent} - \mathbf{v}_{in}. \tag{16}$$

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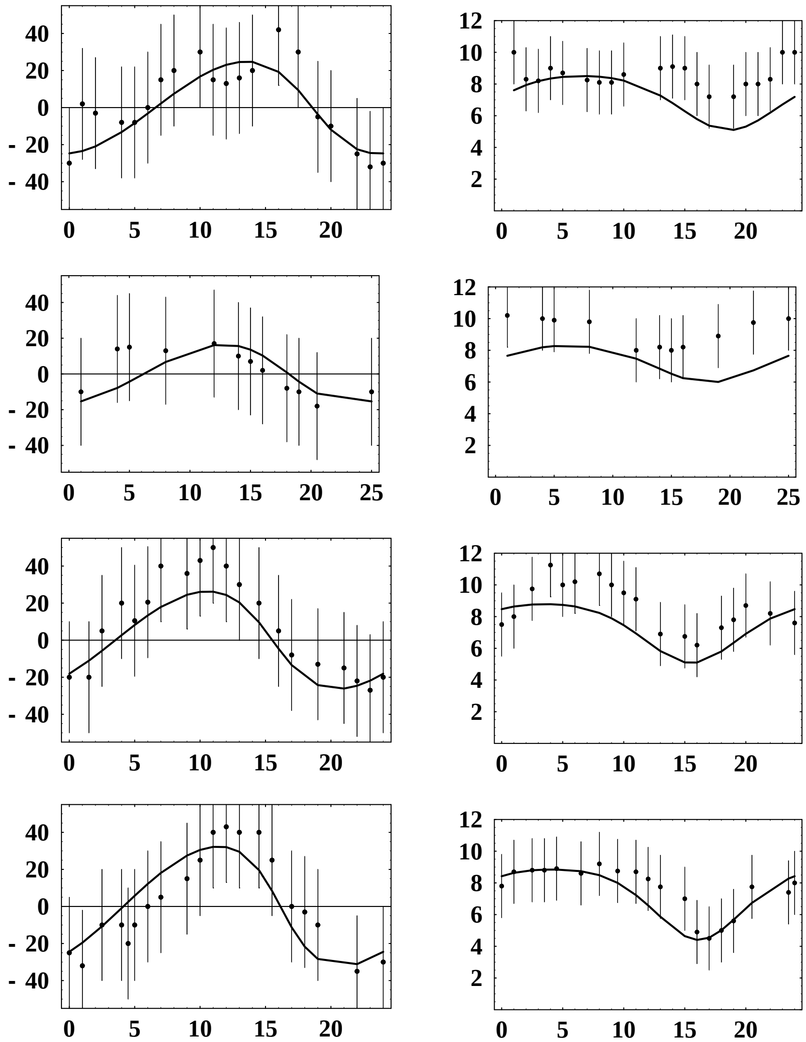

Figure 2: Azimuths (degrees) (left column) and v_M speeds (km/s) (right column) measured by Miller on February 8, 1926 (top row), April 1, 1925, August 1, 1925 and September 15, 1925 (bottom row) plotted against sidereal time (hrs). Error bars are indicative only. Curve shows quantum-foam theory predictions for case of CBR cosmic speed of 365km/s, orbital velocity of 30km/s, quantum gravity in-flow of 42km/s, the k_{air} value and Miller's direction for $\mathbf{v}_{cosmic}$.

We can combine the dielectric effect and the Earth-velocity effect to extract from Miller's data the speed of this in-flow component. For circular orbits the in-flow and tangential speeds are orthogonal, so the actual velocity of the Earth through the quantum foam is given by (16) whereas as Miller of course did not include the $-\mathbf{v}_{in}$ component. From this we easily find that it is $v_R = \sqrt{v_{in}^2 + v_{tangent}^2}$ that sets the scale and not $v_{tangent}$, and so we obtain that the value of v_{in} implied by $\overline{k} > k_{air}$ is given by

$$v_{in} = v_{tangent}\sqrt{\frac{\overline{k}^2}{k_{air}^2} - 1} \tag{17}$$

Using the above $\overline{k}$ value and the value of k_{air} we obtain $v_{in} = 47 \pm 6$km/s. The new physics which unifies gravity and the quantum predicts the in-flow speed to be, at distance R from the Sun,

$$v_{in} = \sqrt{\frac{2GM}{R}}, \tag{18}$$

where M is the mass of the Sun, R is the distance of the Earth from the Sun, and G is Newton's gravitational constant. G is essentially a measure of the rate at which matter effecctively 'dissipates' the quantum-foam. For circular orbits the tangential orbital speed is given by

$$v_{tangent} = \sqrt{\frac{GM}{R}}, \tag{19}$$

giving $v_{tangent} = 30$km/s, and so $v_{in} = \sqrt{2}v_{tangent} = 42$km/s. Hence the value for v_{in} from the Miller data is consistent with the theoretical value. Since it is $v_R = \sqrt{3}v_{tangent}$ and not $v_{tangent}$ that sets the scale we must re-scale Miller's value for v to be $\sqrt{3} \times 210 = 364$km/s, which now compares favourably with the COBE CBR speed.

The gravitational acceleration arises from inhomogeneities in the flow and is given by $\mathbf{g} = (\mathbf{v}_{in}.\nabla)\mathbf{v}_{in}$ in this quantum-foam flow physics [1]. So the Miller experiment actually amounted to the first quantum gravity experiment, and the ability of dielectric-mode interferometers to measure absolute motion made this possible. New dielectric-mode interferometers are being used at Flinders University to measure the quantum-foam radial in-flow speed associated with the Earth's gravity. This component did not contribute to Miller's data as it is perpendicular to the plane of the interferometer.

Miller was also able to extract the direction of $\mathbf{v}_{cosmic}$ from analysis of his observational data using the daily and seasonal time-dependencies apparent in Fig.2 and obtained a right ascension and declination of $(\alpha, \delta) = (17^h, +70^0)$. In Fig.2 are shown the quantum-foam physics 'predictions' for the v_M speeds and azimuths using the projection of $\mathbf{v}$ in (16) onto the plane of the Miller interferometer at Mt.Wilson, using $v_{cosmic} = v_{CBR}$ is 365km/s, the orbital speed is 30km/s and the in-flow speed is 42km/s, the k_{air} value, and the Miller direction for $\mathbf{v}_{cosmic}$. This illustrates that the new physics agrees with Miller's 1925/1926 observational data, both for absolute values and for time variation over each day and seasonally. The Miller data used here was obtained by inspection of hand-drawn figures published in [7] and are not very accurate, and so a complete re-analysis of the data is not possible. The error bars are only indicative and should not be taken as Miller's values.

While the extracted cosmic speed from Miller's data here, and from the Michelson-Morley and Illingworth data in [3], are in excellent agreement with the CBR speed the direction found above is in complete disagreement with the COBE determined direction [5] which is $(\alpha, \delta) = (11.2^h \pm 0.2^h, -7^0 \pm 2^0)$. This COBE direction gives azimuth and v_M speed interferometer predictions that are totally inconsistent with the Miller data in Fig.2. However the two directions are at 90^0 to each other. This suggests that this disagreement might be caused by a definitional problem with the right ascension and declination in the COBE satellite mission. At least this is a prediction of the present work.

It is interesting to return to the Michelson-Morley experimental data of 1887 which since then, with rare exceptions, has been claimed to have given a null result, and so supporting the Einstein assumption that absolute motion has no meaning. In fact Michelson-Morley reported non-null effects, but much smaller than they expected. They made observations of thirty-six complete turns using a $L = 1.1$ meter length air-interferometer in Cleveland, Latitude $41^0 30'$N, with six turns at 12:00 hrs (7:00 hrs ST) on each day of July 8, 9 and 11, 1887 and similarly at 18:00 hrs (13:00 hrs ST) on July 8, 9 and 12, 1887. Their results after averaging over the noon sessions, and also averaging the evening sessions, and also averaging the first half-turn and the last half-turn data, are shown in Fig.3 (the data is available from [7]).

The fringe shifts were extremely small but within their observational capabilities. The fringe shifts actually correspond to a maximum v_M speed of some 8.3km/s, being slighlty lower than Miller's speeds in Fig.2 due to the higher latitude of Cleveland compared to Mt.Wilson. Also plotted in Fig.3 are the quantum-foam physics predictions using in (16) the CBR speed of 365km/s, the orbital speed of 30km/s, the quantum gravity in-flow of 42km/s, the Miller direction and the value of k_{air}, for the time, date and location of the Michelson-Morley experiment. The dependence on rotation angle θ in Fig.3 is $sin(2\theta)$. We see that they observed essentially what the new physics predicts.

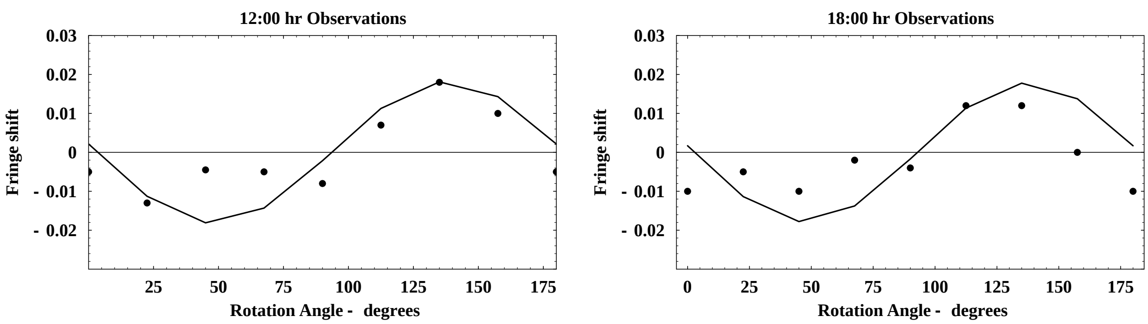

Figure 3: Data shows the 1887 Michelson-Morley averaged fringe shifts for 12:00 hrs on July 8, 9 and 11 (LH plot) and 18:00 hrs on July 8, 9 and 12 (RH plot), as interferometer was rotated through 360 degree, and is average of the two half-turns. Curve shows quantum-foam theory prediction for case of CBR cosmic speed 365km/s, orbit speed of 30km/s, quantum gravity in-flow of 42km/s, the k_{air} value and Miller's direction for $\mathbf{v}_{cosmic}$.

So their results were never null, and can now be fully comprehended. They in-fact performed the first quantum-foam experiment, as revealed by the dielectric effect. Their expected fringe shifts were based on using the Newtonian value of $k = 1$ and on v being atleast 30km/s, due to the Earth's orbital motion, and so predicting fringe shifts 10 times larger than actually seen (the true value for v^2 in (1) is some 10^2 larger but the dielectric effect gives a reduction of approximately 1/1000). Of course that Michelson and Morley saw any effect is solely due to the presence of the air in their interferometer, an effect that neither they nor later generations of physicists ever noticed. Vacuum interferometer experiments of the same era by Joos [10] gave $v_M < 1$km/s, and are consistent with a null effect, as also predicted by the quantum-foam physics. Of course if Michelson and Morley had used glass rods in their interferometer they would have seen effects more than 1000 times larger, and the history of physics over the last 100 years would have been totally different.

The experimental results analysed herein and in [3] show that absolute motion is detectable. This is motion with respect to a quantum-foam system that is space. As well quantum matter effectively acts as a sink for the quantum-foam, and the flow of that quantum-foam towards the Sun has been confirmed in Miller's data. So that experiment was the first quantum gravity experiment. These results are in conflict with the fundamental assumption by Einstein that absolute motion has no meaning and so cannot be measured. Vacuum interferometer experiments do give null results, for example see [10, 11, 12, 13], but they only check the Lorentz contraction effect, and this is common to both theories. So they are unable to distinguish the new physics from the Einstein physics. As well that the interferometer experiments and their results fall into two classes, namely vacuum and dielectric has gone unnoticed. The non-null results from dielectric-mode interferometers have always been rejected on the grounds that they would be in conflict with the many successes of the Special and General Theory of Relativity. However this is not strictly so, and it turns out that these successes survive in the new physics, which actually subsumes the Einstein formalism, even though the absolute motion effect is not in the Einstein physics. Einstein essentially arrived at a valid formalism from a wrong assumption. The new more encompassing physics allows the determination of a physically real foliation of the spacetime construct (the Panlevé-Gullstrand foliation) and so it actually breaks the diffeomorphism symmetry of General Relativity. The results here and in [3] demonstrate that the new physics is an experimentally tested unification of gravity and the quantum.

This paper is dedicated to the memory of Dayton C. Miller of the Case School of Applied Science, Cleveland, Ohio. The author thanks Warren Lawrance for on-going discussions of new-generation dielectric-mode interferometer experiments.

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