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SPECIAL REPORT

A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected

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Data from a new experiment measuring the anisotropy of the one-way speed of EM waves in a coaxial cable, gives the speed of light as $300,000 \pm 400 \pm 20 \text{ km/s}$ in a measured direction $RA=5.5 \pm 2 \text{ hrs}$, $Dec=70 \pm 10^\circ \text{ S}$, is shown to be in excellent agreement with the results from seven previous anisotropy experiments, particularly those of Miller (1925/26), and even those of Michelson and Morley (1887). The Miller gas-mode interferometer results, and those from the RF coaxial cable experiments of Torr and Kolen (1983), De Witte (1991) and the new experiment all reveal the presence of gravitational waves, as indicated by the last \pm variations above, but of a kind different from those supposedly predicted by General Relativity. Miller repeated the Michelson-Morley 1887 gas-mode interferometer experiment and again detected the anisotropy of the speed of light, primarily in the years 1925/1926 atop Mt. Wilson, California. The understanding of the operation of the Michelson interferometer in gas-mode was only achieved in 2002 and involved a calibration for the interferometer that necessarily involved Special Relativity effects and the refractive index of the gas in the light paths. The results demonstrate the reality of the Fitzgerald-Lorentz contraction as an observer independent relativistic effect. A common misunderstanding is that the anisotropy of the speed of light is necessarily in conflict with Special Relativity and Lorentz symmetry — this is explained. All eight experiments and theory show that we have both anisotropy of the speed of light *and* relativistic effects, and that a dynamical 3-space exists — that absolute motion through that space has been repeatedly observed since 1887. These developments completely change fundamental physics and our understanding of reality. “Modern” vacuum-mode Michelson interferometers, particularly the long baseline terrestrial versions, are, by design flaw, incapable of detecting the anisotropy effect and the gravitational waves.

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1 Introduction

Of fundamental importance to physics is whether the speed of light is the same in all directions, as measured say in a laboratory attached to the Earth. This is what is meant by *light speed anisotropy* in the title of this paper. The prevailing belief system in physics has it that the speed of light is isotropic, that there is no preferred frame of reference, that absolute motion has never been observed, and that 3-space does not, and indeed cannot exist. This is the essence of Einstein’s 1905 postulate that the speed of light is independent of the choice of observer. This postulate has determined the course of physics over the last 100 years.

Despite the enormous significance of this postulate there has never been a direct experimental test, that is, in which the one-way travel time of light in vacuum over a set distance has been measured, and repeated for different directions. So how could a science as fundamental and important as physics permit such a key idea to go untested? And what are the consequences for fundamental physics if indeed, as reported herein and elsewhere, that the speed of light is anisotropic, that a dynamical 3-space does exist? This would imply that

if reality is essentially space and matter, with time tracking process and change, then physics has completely missed the existence of that space. If this is the case then this would have to be the biggest blunder ever in the history of science, more so because some physicists have independently detected that anisotropy. While herein we both summarise seven previous detections of the anisotropy and report a new experiment, the implications for fundamental physics have already been substantially worked out. It leads to a new modelling and comprehension of reality known as *Process Physics* [1].

The failure of mainstream physics to understand that the speed of light is anisotropic, that a dynamical 3-space exists, is caused by an ongoing failure to comprehend the operation of the Michelson interferometer, and also by theoretical physicists not understanding that the undisputed successes of special relativity effects, and even Lorentz symmetry, do not imply that the speed of light must be isotropic — this is a mere abuse of logic, as explained later.

The Michelson interferometer is actually a complex instrument. The problem is that the anisotropy of the speed of light affects its actual dimensions and hence its operation: there are actual length contractions of its physical arms. Because the anisotropy of the speed of light is so fundamental it is actually very subtle to design an effective experiment because the sought for effect also affects the instrument in more than one way. This subtlety has been overlooked for some 100 years, until in 2002 the original data was reanalysed using a relativistic theory for the calibration of the interferometer [2].

The new understanding of the operation of the Michelson interferometer is that it can only detect the light speed anisotropy when there is gas in the light paths, as there was in the early experiments. Modern versions have removed the gas and made the instrument totally unable to detect the light speed anisotropy. Even in gas mode the interferometer is a very insensitive device, being 2nd order in v/c and further suppressed in sensitivity by the gas refractive index dependency.

More direct than the Michelson interferometer, but still not a direct measurement, is to measure the one-speed of radio frequency (RF) electromagnetic waves in a coaxial cable, for this permits electronic timing methods. This approach is 1st order in v/c , and independent of the refractive index suppression effect. Nevertheless because it is one-way clocks are required at both ends, as in the Torr and Kolen, and De Witte experiments, and the required length of the coaxial cable was determined, until now, by the stability of atomic clocks over long durations.

The new one-way RF coaxial experiment reported herein utilises a new timing technique that avoids the need for two atomic clocks, by using a very special property of optical fibres, namely that the light speed in optical fibres is isotropic, and is used for transmitting timing information, while in the coaxial cables the RF speed is anisotropic, and is used as the

sensor. There is as yet no explanation for this optical fibre effect, but it radically changes the technology for anisotropy experiments, as well and at the same time that of gravitational wave detectors. In the near future all-optical gravitational wave detectors are possible in desk-top instruments. These gravitational waves have very different properties from those supposedly predicted from General Relativity, although that appears to be caused by errors in that derivation.

As for gravitational waves, it has been realised now that they were seen in the Miller, Torr and Kolen, and De Witte experiments, as they are again observed in the new experiment. Most amazing is that these wave effects also appear to be present in the Michelson-Morley fringe shift data from 1887, as the fringe shifts varied from day to day. So Michelson and Morley should have reported that they had discovered absolute motion, a preferred frame, and also wave effects of that frame, that the speed of light has an anisotropy that fluctuated over and above that caused by the rotation of the Earth.

The first and very successful attempt to look for a preferred frame was by Michelson and Morley in 1887. They did in fact detect the expected anisotropy at the level of ± 8 km/s [3], but only according to Michelson's Newtonian calibration theory. However this result has essentially been ignored ever since as they expected to detect an effect of at least ± 30 km/s, which is the orbital speed of the Earth about the Sun. As Miller recognised the basic problem with the Michelson interferometer is that the calibration of the instrument was then clearly not correctly understood, and most likely wrong [4]. Basically Michelson had used Newtonian physics to calibrate his instrument, and of course we now know that that is completely inappropriate as relativistic effects play a critical role as the interferometer is a 2nd order device ($\sim v^2/c^2$ where v is the speed of the device relative to a physical dynamical 3-space*), and so various effects at that order must be taken into account in determining the calibration of the instrument, that is, what light speed anisotropy corresponds to the observed fringe shifts. It was only in 2002 that the calibration of the Michelson interferometer was finally determined by taking account of relativistic effects [2]. One aspect of that was the discovery that only a Michelson interferometer in gas-mode could detect the light anisotropy, as discussed below. As well the interferometer when used in air is nearly a factor of 2000 less sensitive than that according to the inappropriate Newtonian theory. This meant that the Michelson and Morley anisotropy speed variation was now around 330km/s on average, and as high as 400km/s on some days. Miller was aware of this calibration problem, and resorted to a brilliant indirect method, namely to observe the fringe shifts over a period of a year, and to use the effect of the Earth's orbital speed upon the fringe shifts to arrive at

*In Michelson's era the idea was that v was the speed of light relative to an *ether*, which itself filled space. This dualism has proven to be wrong.

a calibration. The Earth's orbital motion was clearly evident in Miller's data, and using this effect he obtained a light speed anisotropy effect of some 200 km/s in a particular direction. However even this method made assumptions which are now known to be invalid, and correcting his earth-effect calibration method we find that it agrees with the new relativistic and gas effects calibration, and both methods now give a speed of near 400 km/s. This also then agrees with the Michelson-Morley results. Major discoveries like that of Miller must be reproduced by different experiments and by different techniques. Most significantly there are in total seven other experiments that confirm this Miller result, with four being gas-mode Michelson interferometers using either air, helium or a He/Ne mixture in the light path, and three experiments that measure variations in the one-way speed of EM waves travelling through a coaxial cable as the orientation of the cable is changed, with the latest being a high precision technique reported herein and in [5, 6]. This method is 1st order in v/c , so it does not require relativistic effects to be taken into account, as discussed later.

As the Michelson interferometer requires a gas to be present in the light path in order to detect the anisotropy it follows that vacuum interferometers, such as those in [7], are simply inappropriate for the task, and it is surprising that some attempts to detect the anisotropy in the speed of light still use vacuum-mode Michelson interferometers, some years after the 2002 discovery of the need for a gas in the light path [2].

Despite the extensive data collected and analysed by Miller after his fastidious testing and refinements to control temperature effects and the like, and most importantly his demonstration that the effects tracked sidereal time and not solar time, the world of physics has, since publication of the results by Miller in 1933, simply ignored this discovery. The most plausible explanation for this situation is the ongoing misunderstanding by many physicists, but certainly not all, that any anisotropy in the speed of light must necessarily be incompatible with Special Relativity (SR), with SR certainly well confirmed experimentally. This is misunderstanding is clarified. In fact Miller's data can now be used to confirm an important aspect of SR. Even so, ignoring the results of a major experiment simply because they challenge a prevailing belief system is not science — ignoring the Miller experiment has stalled physics for some 70 years.

It is clear that the Miller experiment was highly successful and highly significant, and we now know this because the same results have been obtained by later experiments which used *different* experimental techniques. The most significant part of Miller's rigorous experiment was that he showed that the effect tracked sidereal time and not solar time — this is the acid test which shows that the direction of the anisotropy velocity vector is relative to the stars and not to the position of the Sun. This difference is only some 4 minutes per day, but over a year amounts to a huge 24 hours

effect, and Miller saw that effect and extensively discussed it in his paper. Similarly De Witte in his extensive 1991 coaxial cable experiment [9] also took data for 178 days to again establish the sidereal time effect: over 178 days this effect amounts to a shift in the phase of the signal through some 12 hours! The sidereal effect has also been established in the new coaxial cable experiment by the author from data spanning some 200 days.

The interpretation that has emerged from the Miller and related discoveries is that space exists, that it is an observable and dynamical system, and that the Special Relativity effects are caused by the absolute motion of quantum systems through that space [1, 25]. This is essentially the Lorentz interpretation of Special Relativity, and then the spacetime is merely a mathematical construct. The new understanding has led to an explanation of why Lorentz symmetry manifests despite there being a preferred frame, that is, a local frame in which only therein is the speed of light isotropic. A minimal theory for the dynamics of this space has been developed [1, 25] which has resulted in an explanation of numerous phenomena, such as gravity as a quantum effect [25, 8], the so-called "dark matter" effect, the black hole systematics, gravitational light bending, gravitational lensing, and so [21–25].

The Miller data also revealed another major discovery that Miller himself may not have understood, namely that the anisotropy vector actually fluctuates from hour to hour and day to day even when we remove the manifest effect of the Earth's rotation, for Miller may have interpreted this as being caused by imperfections in his experiment. This means that the flow of space past the Earth displays turbulence or a wave effect: basically the Miller data has revealed what we now call *gravitational waves*, although these are different to the waves supposedly predicted by General Relativity. These wave effects were also present in the Torr and Kolen [10] first coaxial cable experiment at Utah University in 1981, and were again manifest in the De Witte data from 1991. Analysis of the De Witte data has shown that these waves have a fractal structure [9]. The Flinders University Gravitational Waves Detector (also a coaxial cable experiment) was constructed to investigate these waves effects. This sees the wave effects detected by Miller, Torr and Kolen, and by De Witte. The plan of this paper is to first outline the modern understanding of how a gas-mode Michelson interferometer actually operates, and the nature, accuracy and significance of the Miller experiment. We also report the other seven experiments that confirm the Miller discoveries, particularly data from the new high-precision gravity wave detector that detects not only a light speed anisotropy but also the wave effects.

2 Special Relativity and the speed of light anisotropy

It is often assumed that the anisotropy of the speed of light is inconsistent with Special Relativity, that only one or the

other can be valid, that they are mutually incompatible. This misunderstanding is very prevalent in the literature of physics, although this conceptual error has been explained [1]. The error is based upon a misunderstanding of how the logic of theoretical physics works, namely the important difference between an *if* statement, and an *if and only if* statement. To see how this confusion has arisen we need to recall the history of Special Relativity (SR). In 1905 Einstein deduced the SR formalism by assuming, in part, that the speed of light is invariant for all relatively moving observers, although most importantly one must ask just how that speed is defined or is to be measured. The SR formalism then predicted numerous effects, which have been extensively confirmed by experiments over the last 100 years. However this Einstein derivation was an *if* statement, and not an *if and only if* statement. For an *if* statement, that *if A then B*, does not imply the truth of *A* if *B* is found to be true; only an *if and only if* statement has that property, and Einstein did not construct such an argument. What this means is that the validity of the various SR effects does *not* imply that the speed of light must be isotropic. This is actually implicit in the SR formalism itself, for it permits one to use any particular foliation of the 4-dimensional spacetime into a 3-space and a 1-space (for time). Most importantly it does not forbid that one particular foliation be actual. So to analyse the data from gas-mode interferometer experiments we must use the SR effects, and the fringe shifts reveal the preferred frame, an actual 3-space, by revealing the anisotropic speed of light, as Maxwell and Michelson had originally believed.

For “modern” resonant-cavity Michelson interferometer experiments we predict no rotation-induced fringe shifts, unless operated in gas-mode. Unfortunately in analysing the data from the vacuum-mode experiments the consequent null effect is misinterpreted, as in [7], to imply the absence of a preferred direction, of absolute motion. But it is absolute motion which causes the dynamical effects of length contractions, time dilations and other relativistic effects, in accord with Lorentzian interpretation of relativistic effects.

The detection of absolute motion is not incompatible with Lorentz symmetry; the contrary belief was postulated by Einstein, and has persisted for over 100 years, since 1905. So far the experimental evidence is that absolute motion and Lorentz symmetry are real and valid phenomena; absolute motion is motion presumably relative to some substructure to space, whereas Lorentz symmetry parameterises dynamical effects caused by the motion of systems through that substructure. To check Lorentz symmetry we can use vacuum-mode resonant-cavity interferometers, but using gas within the resonant-cavities would enable these devices to detect absolute motion with great precision. As well there are novel wave phenomena that could also be studied, as discussed herein and in [19, 20].

Motion through the structured space, it is argued, induces actual dynamical time dilations and length contractions in

agreement with the Lorentz interpretation of special relativistic effects. Then observers in uniform motion “through” the space will, on measurement of the speed of light using the special but misleading Einstein measurement protocol, obtain always the same numerical value c . To see this explicitly consider how various observers P, P', \dots moving with different speeds through space, measure the speed of light. They each acquire a standard rod and an accompanying standardised clock. That means that these standard rods would agree if they were brought together, and at rest with respect to space they would all have length Δl_0 , and similarly for the clocks. Observer P and accompanying rod are both moving at speed v_R relative to space, with the rod longitudinal to that motion. P then measures the time Δt_R , with the clock at end A of the rod, for a light pulse to travel from end A to the other end B and back again to A . The light travels at speed c relative to space. Let the time taken for the light pulse to travel from $A \rightarrow B$ be t_{AB} and from $B \rightarrow A$ be t_{BA} , as measured by a clock at rest with respect to space*. The length of the rod moving at speed v_R is contracted to

$$\Delta l_R = \Delta l_0 \sqrt{1 - \frac{v_R^2}{c^2}}. \quad (1)$$

In moving from A to B the light must travel an extra distance because the end B travels a distance $v_R t_{AB}$ in this time, thus the total distance that must be traversed is

$$c t_{AB} = \Delta l_R + v_R t_{AB}, \quad (2)$$

similarly on returning from B to A the light must travel the distance

$$c t_{BA} = \Delta l_R - v_R t_{BA}. \quad (3)$$

Hence the total travel time Δt_0 is

$$\Delta t_0 = t_{AB} + t_{BA} = \frac{\Delta l_R}{c - v_R} + \frac{\Delta l_R}{c + v_R} = \quad (4)$$

$$= \frac{2\Delta l_0}{c \sqrt{1 - \frac{v_R^2}{c^2}}}. \quad (5)$$

Because of the time dilation effect for the moving clock

$$\Delta t_R = \Delta t_0 \sqrt{1 - \frac{v_R^2}{c^2}}. \quad (6)$$

Then for the moving observer the speed of light is defined as the distance the observer believes the light travelled ($2\Delta l_0$) divided by the travel time according to the accompanying clock (Δt_R), namely $2\Delta l_0/\Delta t_R = 2\Delta l_R/\Delta t_0$, from above, which is thus the same speed as seen by an observer at rest in the space, namely c . So the speed v_R of the observer through space is not revealed by this procedure, and the observer is erroneously led to the conclusion that the speed of light is always c . This follows from two or more

*Not all clocks will behave in this same “ideal” manner.

observers in manifest relative motion all obtaining the same speed c by this procedure. Despite this failure this special effect is actually the basis of the spacetime Einstein measurement protocol. That this protocol is blind to the absolute motion has led to enormous confusion within physics.

To be explicit the Einstein measurement protocol actually inadvertently uses this special effect by using the radar method for assigning historical spacetime coordinates to an event: the observer records the time of emission and reception of radar pulses ($t_r > t_e$) travelling through space, and then retrospectively assigns the time and distance of a distant event B according to (ignoring directional information for simplicity)

$$T_B = \frac{1}{2} (t_r + t_e), \quad D_B = \frac{c}{2} (t_r - t_e), \quad (7)$$

where each observer is now using the same numerical value of c . The event B is then plotted as a point in an individual geometrical construct by each observer, known as a spacetime record, with coordinates (D_B, T_B) . This is no different to an historian recording events according to some agreed protocol. Unlike historians, who don't confuse history books with reality, physicists do so. We now show that because of this protocol and the absolute motion dynamical effects, observers will discover on comparing their historical records of the same events that the expression

$$\tau_{AB}^2 = T_{AB}^2 - \frac{1}{c^2} D_{AB}^2, \quad (8)$$

is an invariant, where $T_{AB} = T_A - T_B$ and $D_{AB} = D_A - D_B$ are the differences in times and distances assigned to events A and B using the Einstein measurement protocol (7), so long as both are sufficiently small compared with the scale of inhomogeneities in the velocity field.

To confirm the invariant nature of the construct in (8) one must pay careful attention to observational times as distinct from protocol times and distances, and this must be done separately for each observer. This can be tedious. We now demonstrate this for the situation illustrated in Fig. 1.

By definition the speed of P' according to P is $v'_0 = D_B/T_B$ and so $v'_R = v'_0$, where T_B and D_B are the protocol time and distance for event B for observer P according to (7). Then using (8) P would find that $(\tau_{AB}^P)^2 = T_B^2 - \frac{1}{c^2} D_B^2$ since both $T_A=0$ and $D_A=0$, and whence $(\tau_{AB}^P)^2 = (1 - \frac{v'^2_R}{c^2}) T_B^2 = (t'_B)^2$ where the last equality follows from the time dilation effect on the P' clock, since t'_B is the time of event B according to that clock. Then T_B is also the time that P' would compute for event B when correcting for the time-dilation effect, as the speed v'_R of P' through space is observable by P' . Then T_B is the "common time" for event B assigned by both observers. For P' we obtain directly, also from (7) and (8), that $(\tau_{AB}^{P'})^2 = (T'_B)^2 - \frac{1}{c^2} (D'_B)^2 = (t'_B)^2$, as $D'_B = 0$ and $T'_B = t'_B$. Whence for this situation

$$(\tau_{AB}^P)^2 = (\tau_{AB}^{P'})^2, \quad (9)$$

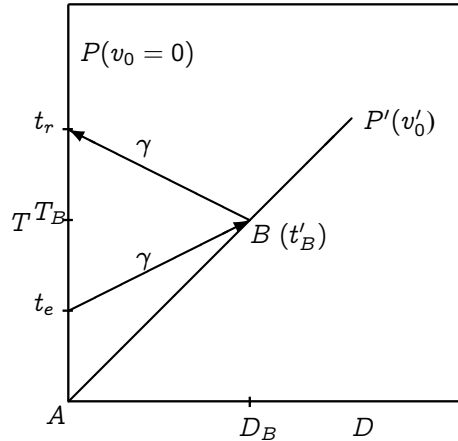


Fig. 1: Here $T - D$ is the spacetime construct (from the Einstein measurement protocol) of a special observer P at rest wrt space, so that $v_0 = 0$. Observer P' is moving with speed v'_0 as determined by observer P , and therefore with speed $v'_R = v'_0$ wrt space. Two light pulses are shown, each travelling at speed c wrt both P and space. Event A is when the observers pass, and is also used to define zero time for each for convenience.

and so the construction (8) is an invariant.

While so far we have only established the invariance of the construct (8) when one of the observers is at rest in space, it follows that for two observers P' and P'' both in absolute motion it follows that they also agree on the invariance of (8). This is easily seen by using the intermediate step of a stationary observer P :

$$(\tau_{AB}^{P'})^2 = (\tau_{AB}^P)^2 = (\tau_{AB}^{P''})^2. \quad (10)$$

Hence the protocol and Lorentzian absolute motion effects result in the construction in (8) being indeed an invariant in general. This is a remarkable and subtle result. For Einstein this invariance was a fundamental assumption, but here it is a derived result, but one which is nevertheless deeply misleading. Explicitly indicating small quantities by Δ prefixes, and on comparing records retrospectively, an ensemble of nearby observers agree on the invariant

$$\Delta\tau^2 = \Delta T^2 - \frac{1}{c^2} \Delta D^2, \quad (11)$$

for any two nearby events. This implies that their individual patches of spacetime records may be mapped one into the other merely by a change of coordinates, and that collectively the spacetime patches of all may be represented by one pseudo-Riemannian manifold, where the choice of coordinates for this manifold is arbitrary, and we finally arrive at the invariant

$$\Delta\tau^2 = g_{\mu\nu}(x) \Delta x^\mu \Delta x^\nu, \quad (12)$$

with $x^\mu = \{D_1, D_2, D_3, T\}$. Eqn. (12) is invariant under the Lorentz transformations

$$x'^\mu = L^\mu_\nu x^\nu, \quad (13)$$

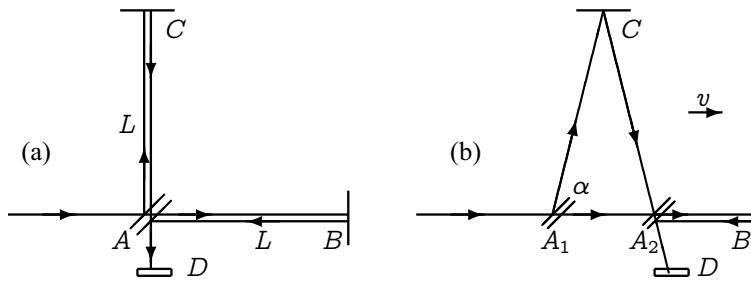


Fig. 2: Schematic diagrams of the Michelson Interferometer, with beamsplitter/mirror at A and mirrors at B and C on arms from A, with the arms of equal length L when at rest. D is a screen or detector. In (a) the interferometer is at rest in space. In (b) the interferometer is moving with speed v relative to space in the direction indicated. Interference fringes are observed at the detector D. If the interferometer is rotated in the plane through 90°, 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 gas. By counting fringe changes the speed v may be determined.

where, for example for relative motion in the x direction, L^μ_ν is specified by

$$\begin{aligned} x' &= \frac{x - vt}{\sqrt{1 - v^2/c^2}}, \\ y' &= y, \\ z' &= z, \\ t' &= \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}}. \end{aligned} \tag{14}$$

So absolute motion and special relativity effects, and even Lorentz symmetry, are all compatible: a possible preferred frame is hidden by the Einstein measurement protocol.

So the experimental question is then whether or not a supposed preferred frame actually exists or not – can it be detected experimentally? The answer is that there are now eight such consistent experiments. In Sect. 4.7 we generalise the Dirac equation to take account of the coupling of the spinor to an actual dynamical space. This reveals again that relativistic effects are consistent with a preferred frame – an actual space. Furthermore this leads to the first derivation of gravity from a deeper theory – gravity turns out to be a quantum matter wave effect.

3 Light speed anisotropy experiments

We now consider the various experiments from over more than 100 years that have detected the anisotropy of the speed of light, and so the existence of an actual dynamical space, an observable preferred frame. As well the experiments, it is now understood, showed that this frame is dynamical, it exhibits time-dependent effects, and that these are “gravitational waves”.

3.1 Michelson gas-mode interferometer

Let us first consider the new understanding of how the Michelson interferometer works. This brilliant but very subtle

device was conceived by Michelson as a means to detect the anisotropy of the speed of light, as was expected towards the end of the 19th century. Michelson used Newtonian physics to develop the theory and hence the calibration for his device. However we now understand that this device detects 2nd order effects in v/c to determine v, and so we must use relativistic effects. However the application and analysis of data from various Michelson interferometer experiments using a relativistic theory only occurred in 2002, some 97 years after the development of Special Relativity by Einstein, and some 115 years after the famous 1887 experiment. As a consequence of the necessity of using relativistic effects it was discovered in 2002 that the gas in the light paths plays a critical role, and that we finally understand how to calibrate the device, and we also discovered, some 76 years after the 1925/26 Miller experiment, what determines the calibration constant that Miller had determined using the Earth’s rotation speed about the Sun to set the calibration. This, as we discuss later, has enabled us to now appreciate that gas-mode Michelson interferometer experiments have confirmed the reality of the Fitzgerald-Lorentz length contraction effect: in the usual interpretation of Special Relativity this effect, and others, is usually regarded as an observer dependent effect, an illusion induced by the spacetime. But the experiments are to the contrary showing that the length contraction effect is an actual observer-independent dynamical effect, as Fitzgerald [27] and Lorentz had proposed [28].

The Michelson interferometer compares the change in the difference between travel times, when the device is rotated, for two coherent beams of light that travel in orthogonal directions between mirrors; the changing time difference being indicated by the shift of the interference fringes during the rotation. This effect is caused by the absolute motion of the device through 3-space with speed v, and that the speed of light is relative to that 3-space, and not relative to the apparatus/observer. However to detect the speed of the apparatus through that 3-space gas must be present in the light paths for purely technical reasons. The post relativistic-

effects theory for this device is remarkably simple. The relativistic Fitzgerald-Lorentz contraction effect causes the arm AB parallel to the absolute velocity to be physically contracted to length

$$L_{||} = L \sqrt{1 - \frac{v^2}{c^2}}. \quad (15)$$

The time t_{AB} to travel AB is set by $Vt_{AB} = L_{||} + vt_{AB}$, while for BA by $Vt_{BA} = L_{||} - vt_{BA}$, where $V = c/n$ is the speed of light, with n the refractive index of the gas present (we ignore here the Fresnel drag effect for simplicity, an effect caused by the gas also being in absolute motion, see [1]). For the total ABA travel time we then obtain

$$t_{ABA} = t_{AB} + t_{BA} = \frac{2LV}{V^2 - v^2} \sqrt{1 - \frac{v^2}{c^2}}. \quad (16)$$

For travel in the AC direction we have, from the Pythagoras theorem for the right-angled triangle in Fig. 1 that $(Vt_{AC})^2 = L^2 + (vt_{AC})^2$ and that $t_{CA} = t_{AC}$. Then for the total ACA travel time

$$t_{ACA} = t_{AC} + t_{CA} = \frac{2L}{\sqrt{V^2 - v^2}}. \quad (17)$$

Then the difference in travel time is

$$\Delta t = \frac{(n^2 - 1)L}{c} \frac{v^2}{c^2} + O\left(\frac{v^4}{c^4}\right). \quad (18)$$

after expanding in powers of v/c . This clearly shows that the interferometer can only operate as a detector of absolute motion when not in vacuum ($n = 1$), namely when the light passes through a gas, as in the early experiments (in transparent solids a more complex phenomenon occurs). A more general analysis [1], including Fresnel drag, gives

$$\Delta t = k^2 \frac{Lv_P^2}{c^3} \cos(2(\theta - \psi)), \quad (19)$$

where $k^2 \approx n(n^2 - 1)$, while neglect of the relativistic Fitzgerald-Lorentz contraction effect gives $k^2 \approx n^3 \approx 1$ for gases, which is essentially the Newtonian theory that Michelson used.

However the above analysis does not correspond to how the interferometer is actually operated. That analysis does not actually predict fringe shifts for the field of view would be uniformly illuminated, and the observed effect would be a changing level of luminosity rather than fringe shifts. As Miller knew the mirrors must be made slightly non-orthogonal, with the degree of non-orthogonality determining how many fringe shifts were visible in the field of view. Miller experimented with this effect to determine a comfortable number of fringes: not too few and not too many. Hicks [29] developed a theory for this effect — however it is not necessary to be aware of this analysis in using the interferometer: the non-orthogonality reduces the symmetry of the device, and

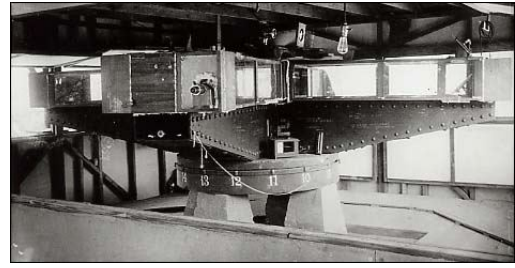


Fig. 3: Miller's interferometer with an effective arm length of $L = 32$ m achieved by multiple reflections. Used by Miller on Mt. Wilson to perform the 1925-1926 observations of absolute motion. The steel arms weighed 1200 kilograms and floated in a tank of 275 kilograms of Mercury. From Case Western Reserve University Archives.

instead of having period of 180° the symmetry now has a period of 360° , so that to (19) we must add the extra term in

$$\Delta t = k^2 \frac{Lv_P^2}{c^3} \cos(2(\theta - \psi)) + a \cos(\theta - \beta). \quad (20)$$

Miller took this effect into account when analysing his data. The effect is apparent in Fig. 5, and even more so in the Michelson-Morley data in Fig. 4.

The interferometers are operated with the arms horizontal, as shown by Miller's interferometer in Fig. 3. Then in (20) θ is the azimuth of one arm relative to the local meridian, while ψ is the azimuth of the absolute motion velocity projected onto the plane of the interferometer, with projected component v_P . Here the Fitzgerald-Lorentz contraction is a real dynamical effect of absolute motion, unlike the Einstein spacetime view that it is merely a spacetime perspective artifact, and whose magnitude depends on the choice of observer. The instrument is operated by rotating at a rate of one rotation over several minutes, and observing the shift in the fringe pattern through a telescope during the rotation. Then fringe shifts from six (Michelson and Morley) or twenty (Miller) successive rotations are averaged to improve the signal to noise ratio, and the average sidereal time noted, giving the Michelson-Morley data in Fig. 4. or the Miller data like that in Fig. 5. The form in (20) is then fitted to such data by varying the parameters v_P , ψ , a and β . The data from rotations is sufficiently clear, as in Fig. 5, that Miller could easily determine these parameters from a graphical plot.

However Michelson and Morley implicitly assumed the Newtonian value $k=1$, while Miller used an indirect method to estimate the value of k , as he understood that the Newtonian theory was invalid, but had no other theory for the interferometer. Of course the Einstein postulates, as distinct from Special Relativity, have that absolute motion has no meaning, and so effectively demands that $k=0$. Using $k=1$ gives only a nominal value for v_P , being some 8–9 km/s for the Michelson and Morley experiment, and some 10 km/s from Miller; the difference arising from the different latitu-

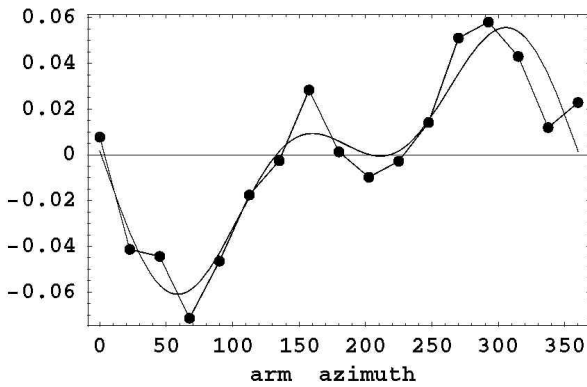


Fig. 4: Example of Michelson-Morley fringe shifts from average of 6 rotations measured every 22.5° , in fractions of a wavelength $\Delta\lambda/\lambda$, vs arm azimuth $\theta(\text{deg})$, from Cleveland, Ohio, July 11, 1887 12:00 hrs local time or 7:00 hrs local sidereal time. This shows the quality of the fringe shift data that Michelson and Morley obtained. The curve is the best fit using the form in (20) which includes the Hick's $\cos(\theta - \beta)$ component that is required when the mirrors are not orthogonal, and gives $\psi = 140^\circ$, or 40° measured from South, compared to the Miller ψ for August at 7:00 hrs local sidereal time in Fig. 6, and a projected speed of $v_P = 400 \text{ km/s}$. The Hick's effect is much larger in this data than in the Miller data in Fig. 5.

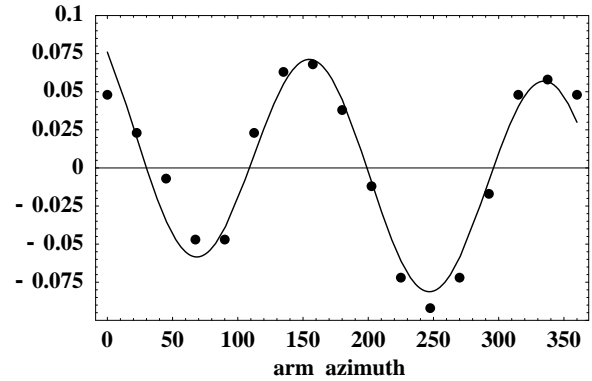


Fig. 5: Typical Miller rotation-induced fringe shifts from average of 20 rotations, measured every 22.5° , in fractions of a wavelength $\Delta\lambda/\lambda$, vs arm azimuth $\theta(\text{deg})$, measured clockwise from North, from Cleveland Sept. 29, 1929 16:24 UT; 11:29 hrs average local sidereal time. The curve is the best fit using the form in (20) which includes the Hick's $\cos(\theta - \beta)$ component that is required when the mirrors are not orthogonal, and gives $\psi = 158^\circ$, or 22° measured from South, and a projected speed of $v_P = 351 \text{ km/s}$. This process was repeated some 8,000 times over days throughout 1925/1926 giving, in part, the data in Fig. 6 and Fig. 18.

des of Cleveland and Mt. Wilson, and from Michelson and Morley taking data at limited times. So already Miller knew that his observations were consistent with those of Michelson and Morley, and so the important need for reproducibility was being confirmed.

3.2 Michelson-Morley experiment

The Michelson and Morley air-mode interferometer fringe shift data was based upon a total of only 36 rotations in July 1887, revealing the nominal speed of some 8–9 km/s when analysed using the prevailing but incorrect Newtonian theory which has $k = 1$ in (20), and this value was known to Michelson and Morley. Including the Fitzgerald-Lorentz dynamical contraction effect as well as the effect of the gas present as in (20) we find that $n_{air} = 1.00029$ gives $k^2 = 0.00058$ for air, which explains why the observed fringe shifts were so small. The example in Fig. 4 reveals a speed of 400 km/s with an azimuth of 40° measured from south at 7:00 hrs local sidereal time. The data is clearly very consistent with the expected form in (20). They rejected their own data on the sole but spurious ground that the value of 8 km/s was smaller than the speed of the Earth about the Sun of 30km/s. What their result really showed was that (i) absolute motion had been detected because fringe shifts of the correct form, as in (20), had been detected, and (ii) that the theory giving $k^2 = 1$ was wrong, that Newtonian physics had failed. Michelson and Morley in 1887 should have announced that the speed of light did depend of the direction of travel, that the speed was relative to an actual physical 3-space. However contrary to their own data they

concluded that absolute motion had not been detected. This bungle has had enormous implications for fundamental theories of space and time over the last 100 years, and the resulting confusion is only now being finally corrected, albeit with fierce and spurious objections.

3.3 Miller interferometer

It was Miller [4] who saw the flaw in the 1887 paper and realised that the theory for the Michelson interferometer must be wrong. To avoid using that theory Miller introduced the scaling factor k , even though he had no theory for its value. He then used the effect of the changing vector addition of the Earth's orbital velocity and the absolute galactic velocity of the solar system to determine the numerical value of k , because the orbital motion modulated the data, as shown in Fig. 6. By making some 8,000 rotations of the interferometer at Mt. Wilson in 1925/26 Miller determined the first estimate for k and for the absolute linear velocity of the solar system. Fig. 5 shows typical data from averaging the fringe shifts from 20 rotations of the Miller interferometer, performed over a short period of time, and clearly shows the expected form in (20) (only a linear drift caused by temperature effects on the arm lengths has been removed — an effect also removed by Michelson and Morley and also by Miller). In Fig. 5 the fringe shifts during rotation are given as fractions of a wavelength, $\Delta\lambda/\lambda = \Delta t/T$, where Δt is given by (20) and T is the period of the light. Such rotation-induced fringe shifts clearly show that the speed of light is different in different directions. The claim that Michelson interferometers, operating in gas-mode, do not produce fringe shifts under

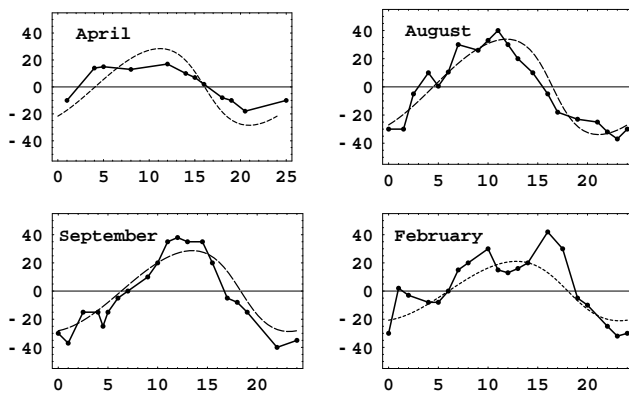


Fig. 6: Miller azimuths ψ , measured from south and plotted against sidereal time in hours, showing both data and best fit of theory giving $v_{cosmic} = 433$ km/s in the direction (RA = 5.2^{hr}, Dec = -67°), and using $n = 1.000226$ appropriate for the altitude of Mt. Wilson. The azimuth data gives a clearer signal than the speed data in Fig. 18. The data shows that the time when the azimuth ψ is zero tracks sidereal time, with the zero times being approximately 5 hrs and 17 hrs. However these times correspond to very different local times, for from April to August, for example, there is a shift of 8 hrs in the local time for these crossings. This is an enormous effect. Again this is the acid test for light speed anisotropy experiments when allowing the rotation of the Earth to change the orientation of the apparatus. The zero crossing times are when the velocity vector for absolute motion when projected onto the plane of the interferometer lines up with the local meridian. As well we see variations throughout these composite days with the crossing times changing by as much as ± 3 hrs, The same effect, and perhaps even larger, is seen in the Flinders data in Fig. 15. The above plots also show a distinctive signature, namely the change from month to month. This is caused by the vector addition of the Earth's orbital velocity of 30 km/s, the Sun's spatial in-flow velocity of 42 km/s at the Earth's distance and the cosmic velocity changing over a year. This is the effect that Miller used to calibrate his interferometer. However he did not know of the Sun in-flow component. Only after taking account of that effect does this calibration method agree with the results from the calibration method using Special Relativity, as in (20).

rotation is clearly incorrect. But it is that claim that lead to the continuing belief, within physics, that absolute motion had never been detected, and that the speed of light is invariant. The value of ψ from such rotations together lead to plots like those in Fig. 6, which show ψ from the 1925/1926 Miller [4] interferometer data for four different months of the year, from which the RA = 5.2 hr is readily apparent. While the orbital motion of the Earth about the Sun slightly affects the RA in each month, and Miller used this effect to determine the value of k , the new theory of gravity required a reanalysis of the data [1, 19], revealing that the solar system has a large observed galactic velocity of some 420 ± 30 km/s in the direction (RA = 5.2 hr, Dec = -67°). This is different from the speed of 369 km/s in the direction (RA = 11.20 hr, Dec = -7.22°) extracted from the Cosmic

Microwave Background (CMB) anisotropy, and which describes a motion relative to the distant universe, but not relative to the local 3-space. The Miller velocity is explained by galactic gravitational in-flows [1].

3.4 Other gas-mode Michelson interferometer experiments

Two old interferometer experiments, by Illingworth [11] and Joos [12], used helium, enabling the refractive index effect to be recently confirmed, because for helium, with $n = 1.000036$, we find that $k^2 = 0.00007$. Until the refractive index effect was taken into account the data from the helium-mode experiments appeared to be inconsistent with the data from the air-mode experiments; now they are seen to be consistent [1]. Ironically helium was introduced in place of air to reduce any possible unwanted effects of a gas, but we now understand the essential role of the gas. The data from an interferometer experiment by Jaseja *et al.* [13], using two orthogonal masers with a He-Ne gas mixture, also indicates that they detected absolute motion, but were not aware of that as they used the incorrect Newtonian theory and so considered the fringe shifts to be too small to be real, reminiscent of the same mistake by Michelson and Morley. The Michelson interferometer is a 2nd order device, as the effect of absolute motion is proportional to $(v/c)^2$, as in (20), but 1st order devices are also possible and the coaxial cable experiments described next are in this class. The experimental results and the implications for physics have been extensively reported in [1, 14, 15, 16, 17, 18].

3.5 Coaxial cable speed of EM waves anisotropy experiments

Rather than use light travel time experiments to demonstrate the anisotropy of the speed of light another technique is to measure the one-way speed of radio waves through a coaxial electrical cable. While this not a direct "ideal" technique, as then the complexity of the propagation physics comes into play, it provides not only an independent confirmation of the light anisotropy effect, but also one which takes advantage of modern electronic timing technology.

3.6 Torr-Kolen coaxial cable anisotropy experiment

The first one-way coaxial cable speed-of-propagation experiment was performed at the Utah University in 1981 by Torr and Kolen. This involved two rubidium clocks placed approximately 500 m apart with a 5 MHz radio frequency (RF) signal propagating between the clocks via a buried nitrogen-filled coaxial cable maintained at a constant pressure of 2 psi. Torr and Kolen found that, while the round speed time remained constant within 0.0001% c , as expected from Sect. 2, variations in the one-way travel time were observed. The maximum effect occurred, typically, at the times predicted using the Miller galactic velocity, although

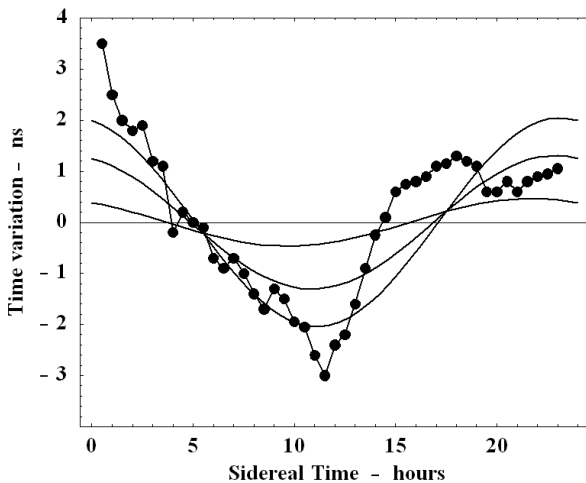


Fig. 7: Data from one day of the Torr-Kolen coaxial cable anisotropy experiment. Smooth curves show variations in travel times when the declination is varied by $\pm 10^\circ$ about the direction ($RA = 5.2^{\text{hr}}$, $Dec = -67^\circ$), for a cosmic speed of 433 km/s. Most importantly the dominant feature is consistent with the predicted local sidereal time.

Torr and Kolen appear to have been unaware of the Miller experiment. As well Torr and Kolen reported fluctuations in both the magnitude, from 1–3 ns, and the time of maximum variations in travel time. These effects are interpreted as arising from the turbulence in the flow of space past the Earth. One day of their data is shown in Fig. 7.

3.7 De Witte coaxial cable anisotropy experiment

During 1991 Roland De Witte performed a most extensive RF coaxial cable travel-time anisotropy experiment, accumulating data over 178 days. His data is in complete agreement with the Michelson-Morley 1887 and Miller 1925/26 interferometer experiments. The Miller and De Witte experiments will eventually be recognised as two of the most significant experiments in physics, for independently and using different experimental techniques they detected essentially the same velocity of absolute motion. But also they detected turbulence in the flow of space past the Earth — none other than gravitational waves. The De Witte experiment was within Belgacom, the Belgium telecommunications company. This organisation had two sets of atomic clocks in two buildings in Brussels separated by 1.5 km and the research project was an investigation of the task of synchronising these two clusters of atomic clocks. To that end 5 MHz RF signals were sent in both directions through two buried coaxial cables linking the two clusters. The atomic clocks were caesium beam atomic clocks, and there were three in each cluster: A1, A2 and A3 in one cluster, and B1, B2, and B3 at the other cluster. In that way the stability of the clocks could be established and monitored. One cluster was in a building

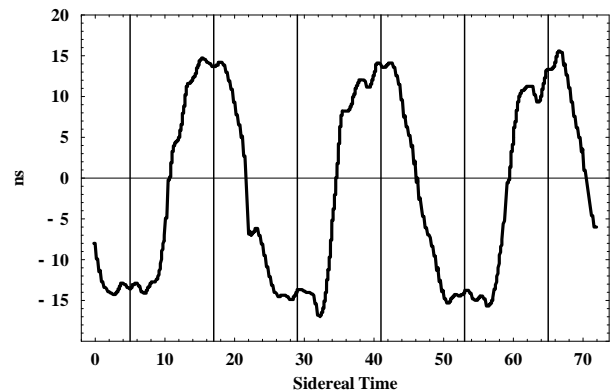


Fig. 8: Variations in twice the one-way travel time, in ns, for an RF signal to travel 1.5 km through a coaxial cable between Rue du Marais and Rue de la Paille, Brussels. An offset has been used such that the average is zero. The cable has a North-South orientation, and the data is \pm difference of the travel times for NS and SN propagation. The sidereal time for maximum effect of ~ 5 hr and ~ 17 hr (indicated by vertical lines) agrees with the direction found by Miller. Plot shows data over 3 sidereal days and is plotted against sidereal time. The fluctuations are evidence of turbulence of gravitational waves.

on Rue du Marais and the second cluster was due south in a building on Rue de la Paille. Digital phase comparators were used to measure changes in times between clocks within the same cluster and also in the one-way propagation times of the RF signals. At both locations the comparison between local clocks, A1-A2 and A1-A3, and between B1-B2, B1-B3, yielded linear phase variations in agreement with the fact that the clocks have not exactly the same frequencies together with a short term and long term phase noise. But between distant clocks A1 toward B1 and B1 toward A1, in addition to the same linear phase variations, there is also an additional clear sinusoidal-like phase undulation with an approximate 24 hr period of the order of 28 ns peak to peak, as shown in Fig. 8. The possible instability of the coaxial lines cannot be responsible for the observed phase effects because these signals are in phase opposition and also because the lines are identical (same place, length, temperature, etc...) causing the cancellation of any such instabilities. As well the experiment was performed over 178 days, making it possible to measure with an accuracy of 25 s the period of the phase signal to be the sidereal day (23 hr 56 min).

Changes in propagation times were observed over 178 days from June 3 to November 27, 1991. A sample of the data, plotted against sidereal time for just three days, is shown in Fig. 8. De Witte recognised that the data was evidence of absolute motion but he was unaware of the Miller experiment and did not realise that the Right Ascensions for minimum/maximum propagation time agreed almost exactly with that predicted using the Miller's direction ($RA = 5.2$ hr, $Dec = -67^\circ$). In fact De Witte expected that the direction of absolute motion should have been in the CMB direction, but

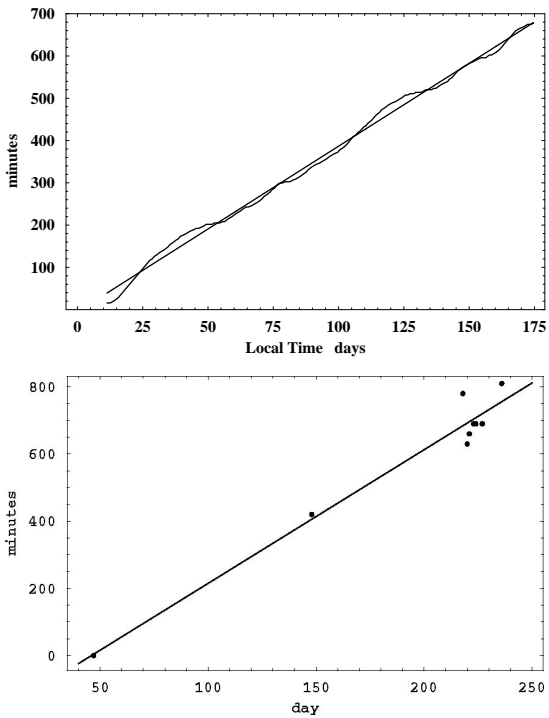


Fig. 9: **Upper:** Plot from the De Witte data of the negative of the drift of the cross-over time between minimum and maximum travel-time variation each day (at $\sim 10\text{hr} \pm 1\text{hr ST}$) versus local solar time for some 180 days. The straight line plot is the least-squares fit to the experimental data, giving an average slope of 3.92 minutes/day. The time difference between a sidereal day and a solar day is 3.93 minutes/day. This demonstrates that the effect is related to sidereal time and not local solar time. **Lower:** Analogous sidereal effect seen in the Flinders experiment. Due to on-going developments the data is not available for all days, but sufficient data is present to indicate a time shift of 3.97 minutes/day. This data also shows greater fluctuations than indicated by the De Witte data, presumably because De Witte used more extensive data averaging.

that would have given the data a totally different sidereal time signature, namely the times for maximum/minimum would have been shifted by 6 hrs. The declination of the velocity observed in this De Witte experiment cannot be determined from the data as only three days of data are available. The De Witte data is analysed in Sect. 4.7 and assuming a declination of 60° S a speed of 430 km/s is obtained, in good agreement with the Miller speed and Michelson-Morley speed. So a different and non-relativistic technique is confirming the results of these older experiments. This is dramatic.

De Witte did however report the sidereal time of the cross-over time, that is in Fig. 8 for all 178 days of data. That showed, as in Fig. 9, that the time variations are correlated with sidereal time and not local solar time. A least-squares best fit of a linear relation to that data gives that the cross-over time is retarded, on average, by 3.92 minutes per solar day. This is to be compared with the fact that a sidereal day

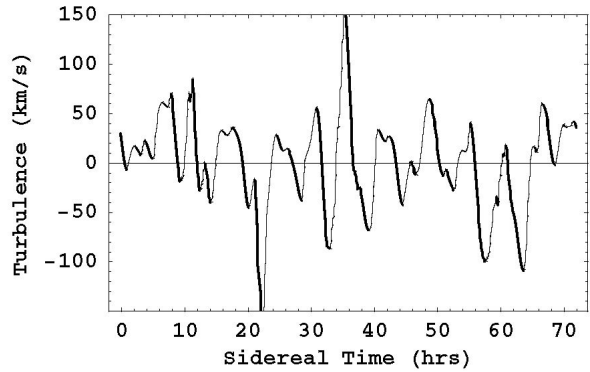


Fig. 10: Shows the speed fluctuations, essentially “gravitational waves” observed by De Witte in 1991 from the measurement of variations in the RF coaxial-cable travel times. This data is obtained from that in Fig. 8 after removal of the dominant effect caused by the rotation of the Earth. Ideally the velocity fluctuations are three-dimensional, but the De Witte experiment had only one arm. This plot is suggestive of a fractal structure to the velocity field. This is confirmed by the power law analysis in [8, 9].

is 3.93 minutes shorter than a solar day. So the effect is certainly galactic and not associated with any daily thermal effects, which in any case would be very small as the cable is buried. Miller had also compared his data against sidereal time and established the same property, namely that the diurnal effects actually tracked sidereal time and not solar time, and that orbital effects were also apparent, with both effects apparent in Fig. 6.

The dominant effect in Fig. 8 is caused by the rotation of the Earth, namely that the orientation of the coaxial cable with respect to the average direction of the flow past the Earth changes as the Earth rotates. This effect may be approximately unfolded from the data leaving the gravitational waves shown in Fig. 10. This is the first evidence that the velocity field describing the flow of space has a complex structure, and is indeed fractal. The fractal structure, i. e. that there is an intrinsic lack of scale to these speed fluctuations, is demonstrated by binning the absolute speeds and counting the number of speeds within each bin, as discussed in [8, 9]. The Miller data also shows evidence of turbulence of the same magnitude. So far the data from three experiments, namely Miller, Torr and Kolen, and De Witte, show turbulence in the flow of space past the Earth. This is what can be called gravitational waves. This can be understood by noting that fluctuations in the velocity field induce ripples in the mathematical construct known as spacetime, as in (32). Such ripples in spacetime are known as gravitational waves.

4 Flinders University gravitational wave detector

In February 2006 first measurements from a gravitational wave detector at Flinders University, Adelaide, were taken. This detector uses a novel timing scheme that overcomes the limitations associated with the two previous coaxial cable

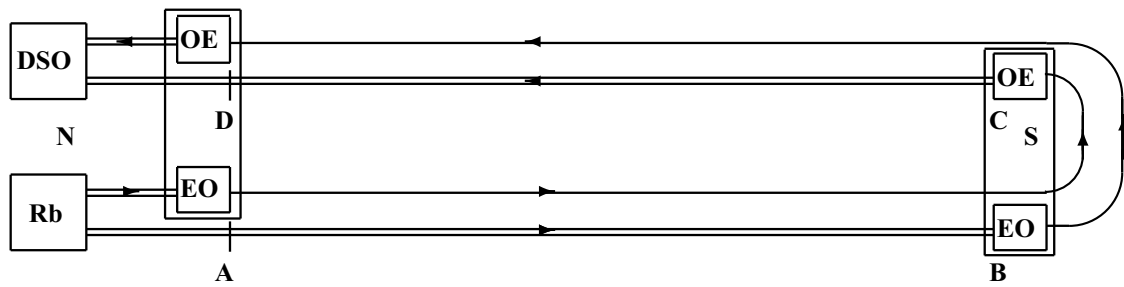


Fig. 11: Schematic layout of the Flinders University Gravitational Wave Detector. Double lines denote coaxial cables, and single lines denote optical fibres. The detector is shown in Fig. 12 and is orientated NS along the local meridian, as indicated by direction D in Fig. 16. Two 10 MHz RF signals come from the Rubidium atomic clock (Rb). The Electrical to Optical converters (EO) use the RF signals to modulate $1.3 \mu\text{m}$ infrared signals that propagate through the single-mode optical fibres. The Optical to Electrical converters (OE) demodulate that signal and give the two RF signals that finally reach the Digital Storage Oscilloscope (DSO), which measures their phase difference. Pairs of E/O and O/E are grouped into one box. Overall this apparatus measures the *difference* in EM travel time from A to B compared to C to D. All other travel times cancel in principle, though in practice small differences in cable or fibre lengths need to be electronically detected by the looping procedure. The key effects are that the propagation speeds through the coaxial cables and optical fibres respond differently to their absolute motion through space. The special optical fibre propagation effect is discussed in the text. Sections AB and CD each have length 5.0 m. The fibres and coaxial cable are specially manufactured to have negligible variation in travel speed with variation in temperature. The zero-speed calibration point can be measured by looping the arm back onto itself, as shown in Fig. 13, because then the 1st order in v/c effect cancels, and only 2nd order effects remain, and these are much smaller than the noise levels in the system. This detector is equivalent to a one-way speed measurement through a single coaxial cable of length 10 m, with an atomic clock at each end to measure changes in travel times. However for 10 m coaxial cable that would be impractical because of clock drifts. With this set-up the travel times vary by some 25 ps over one day, as shown in Figs.14 and 17. The detector was originally located in the author's office, as shown in Fig. 12, but was later located in an underground laboratory where temperature variations were very slow. The travel time variations over 7 days are shown in Fig. 15.

experiments. The intention in such experiments is simply to measure the one-way travel time of RF waves propagating through the coaxial cable. To that end one would apparently require two very accurate clocks at each end, and associated RF generation and detection electronics.

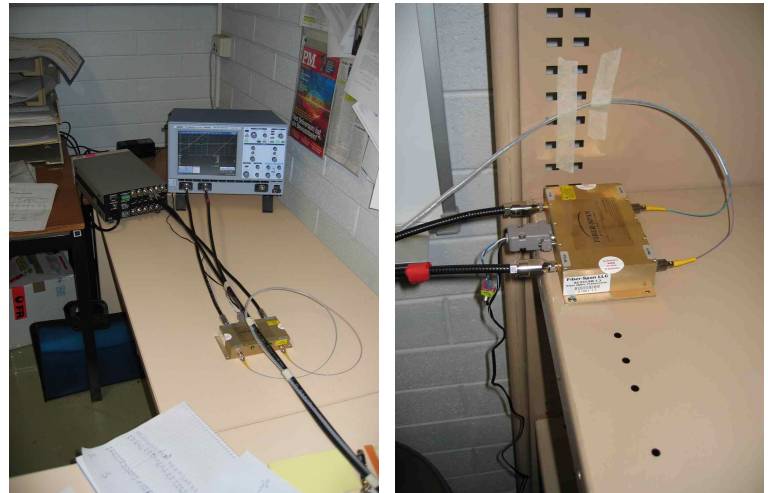
However the major limitation is that even the best atomic clocks are not sufficiently accurate over even a day to make such measurements to the required accuracy, unless the cables are of order of a kilometre or so in length, and then temperature control becomes a major problem. The issue is that the time variations are of the order of 25 ps per 10 meters of cable. To measure that requires time measurements accurate to, say, 1 ps. But atomic clocks have accuracies over one day of around 100 ps, implying that lengths of around 1 kilometre would be required, in order for the effect to well exceed timing errors. Even then the atomic clocks must be brought together every day to resynchronise them, or use De Witte's method of multiple atomic clocks. However at Flinders University a major breakthrough for this problem was made when it was discovered that unlike coaxial cables, the movement of optical fibres through space does not affect the propagation speed of light through them. This is a very strange effect and at present there is no explanation for it.

4.1 Optical fibre effect

This effect was discovered by Lawrance, Drury and the author, using optical fibres in a Michelson interferometer arrangement, where the effective path length in each arm was

4 metres of fibre. So rather than having light pass through a gas, and being reflected by mirrors, here the light propagates through fibres and, where the mirrors would normally be located, a 180 degree bend in the fibres is formed. The light emerging from the two fibres is directed to a common region on a screen, and the expected fringe shifts were seen. However, and most dramatically, when the whole apparatus was rotated no shift in the fringe shifts was seen, unlike the situation with light passing through a gas as above. This result implied that the travel time in each arm of the fibre was unaffected by the orientation of that arm to the direction of the spatial flow. While no explanation has been developed for this effect, other than the general observation that the propagation speed in optical fibres depends on refractive index profiles and transverse and longitudinal Lorentz contraction effects, as in solids these are coupled by the elastic properties of the solid. Nevertheless this property offered a technological leap forward in the construction of a compact coaxial cable gravitational wave detector. This is because timing information can be sent though the fibres in a way that is not affected by the orientation of the fibres, while the coaxial cables do respond to the anisotropy of the speed of EM radiation in vacuum. Again why they respond in this way is not understood. All we have is that fibres and coaxial cables respond differently. So this offers the opportunity to have a coaxial cable one-way speed measurement set up, but using only one clock, as shown in Fig. 11. Here we have one clock at one end of the coaxial cable, and the arrival time of the RF signal at the other end is used to

Fig. 12: The Flinders University Gravitational Wave Detector located in the author's office, showing the Rb atomic clock and Digital Storage Oscilloscope (DSO) at the Northern end of the NS 5 m cable run. In the foreground is one Fibre Optic Transceiver. The coaxial cables are black, while the optical fibres are tied together in a white plastic sleeve, except just prior to connecting with the transceiver. The second photograph shows the other transceiver at the Southern end. Most of the data reported herein was taken when the detector was relocated to an isolated underground laboratory with the transceivers resting on a concrete floor for temperature stabilisation.



modulate a light signal that returns to the starting end via an optical fibre. The return travel time is constant, being independent of the orientation of the detector arm, because of this peculiar property of the fibres. In practice one uses two such arrangements, with the RF directions opposing one another. This has two significant advantages, (i) that the effective coaxial cable length of 10 meters is achieved over a distance of just 5 meters, so the device is more easily accommodated in a temperature controlled room, and (ii) temperature variations in that room have a smaller effect than expected because it is only temperature differences between the cables that have any net effect. Indeed with specially constructed phase compensated fibre and coaxial cable, having very low speed-sensitivity to temperature variations, the most temperature sensitive components are the optical fibre transceivers (E/O and O/E in Fig. 11).

4.2 Experimental components

Rubidium Atomic Clock: Stanford Research System FS725 Rubidium Frequency Standard. Multiple 10MHz RF outputs. Different outputs were used for the two arms of the detector.

Digital Storage Oscilloscope: LeCroy WaveRunner WR6051A 500 MHz 2-channel Digital Storage Oscilloscope (DSO). Jitter Noise Floor 2 ps rms. Clock Accuracy ≤ 5 pm. DSO averaging set at 5000, and generating time readings at 440/minute. Further averaged in DSO over 60 seconds, giving stored data stream at one data point/minute. The data was further running-averaged over a 60 minute interval. Connecting the Rb clock directly to the DSO via its two channels showed a long-term accuracy of ± 1 ps rms with this setup.

Fibre Optic Transceivers: Fiber-Span AC231-EB-1-3 RF/Fiber Optic Transceiver (O/E and E/O). Is a linear extended band (5–2000 MHz) low noise RF fibre optic transceiver for single mode $1.3 \mu\text{m}$ fibre optic wireless systems, with independent receiver and transmitter. RF interface is a 50Ω connector and the optical connector is a low reflection FC/APC connector. Temperature dependence of phase delay is not



Fig. 13: The Flinders University Gravitational Wave Detector showing the cables formed into a loop. This configuration enables the calibration of the detector. The data from such a looping is shown in Fig. 14, but when the detector was relocated to an isolated underground laboratory.

measured yet. The experiment is operated in a uniform temperature room, so that phase delays between the two transceivers cancel to some extent.

Coaxial Cable: Andrews FSJ1-50A Phase Stabilised 50Ω Coaxial Cable. Travel time temperature dependence is $0.026 \text{ ps/m}^\circ\text{C}$. The speed of RF waves in this cable is $c/n = 0.84 c$, arising from the dielectric having refractive index $n = 1.19$. As well temperature effects cancel because the two coaxial cables are tied together, and so only temperature differences between adjacent regions of the cables can have any effect. If such temperature differences are $< 1^\circ\text{C}$, then temperature generated timing errors from this source should be < 0.3 ps for the 10 m.

Optical Fibre: Sumitomo Electric Industries Ind. Ltd Japan Phase Stabilised Optical Fibre (PSOF) – single mode. Uses Liquid Crystal Polymer (LCP) coated single mode optical fibre, with this coating designed to make the travel time temperature dependence $< 0.002 \text{ ps/m}^\circ\text{C}$ very small compared

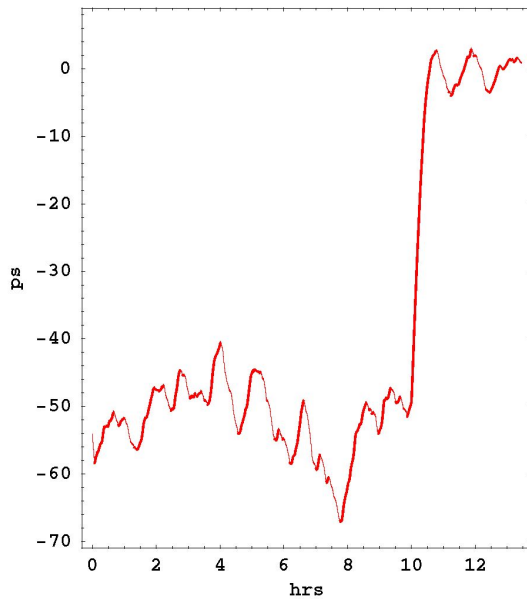


Fig. 14: The detector arm was formed into a loop at approximately 10:00hrs local time. With the system still operating time averaging causes the trace to interpolate during this procedure, as shown. This looping effect is equivalent to having $v = 0$, which defines the value of $\Delta\tau$. In plotting the times here the zero time is set so that then $\Delta\tau = 0$. Now the detector is calibrated, and the times in this figure are absolute times. The times are the N to S travel time subtracted from the shorter S to N travel time, and hence are negative numbers. This demonstrates that the flow of space past the Earth is essentially from south to north, as shown in Fig. 16. When the arms are straight, as before 10:00hrs we see that on average the two travel times differ by some 55 ps. This looping effect is a critical test for the detector. It clearly shows the effect of absolute motion upon the RF travel times. As well we see Earth rotation, wave and converter noise effects before 10:00hrs, and converter noise and some small signal after 10:00hrs, caused by an imperfect circle. From this data (24) and (25) give $\delta = 72^\circ$ S and $v = 418$ km/s.

to normal fibres (0.07 ps/m/°C). As well temperature effects cancel because the two optical fibres are tied together, and so only temperature differences between adjacent regions of the fibres can have any effect. If such temperature differences are $< 1^\circ\text{C}$, then temperature generated timing errors from this source should be < 0.02 ps for the 10 m. Now only Furukawa Electric Ind. Ltd Japan manufacturers PSOF.

Photographs of the Flinders detector are shown in Fig. 12. Because of the new timing technology the detector is now small enough to permit the looping of the detector arm as shown in Fig. 13. This enables a key test to be performed as in the loop configuration the signal should disappear, as then the device acts as though it were located at rest in space, because the actual effects of the absolute motion cancel. The striking results from this test are shown in Fig. 14. As well this key test also provides a means of calibrating the detector.

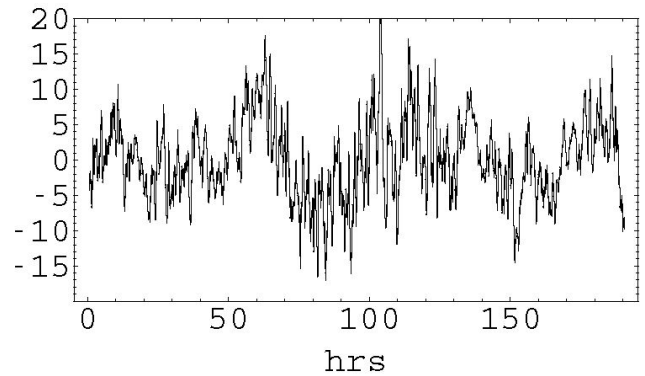


Fig. 15: RF travel time variations in picoseconds (ps) for RF waves to travel through, effectively, 10 meters of coaxial cable orientated in a NS direction. The data is plotted against local Adelaide time for the days August 18–25, 2006. The zero of the travel time variations is arbitrary. The data shows fluctuations identified as earth rotation effect and gravitational waves. These fluctuations exceed those from timing errors in the detector.

4.3 All-optical detector

The unique optical fibre effect permits an even more compact gravitational wave detector. This would be an all-optical system 1st order in v/c device, with light passing through vacuum, or just air, as well as optical fibres. The travel time through the fibres is, as above, unaffected by orientation of the device, while the propagation time through the vacuum is affected by orientation, as the device is moving through the local space.

In this system the relative time differences can be measured using optical interference of the light from the vacuum and fibre components. Then it is easy to see that the vacuum path length needs only be some 5 cm. This makes the construction of a three orthogonal arm even simpler. It would be a cheap bench-top box. In which case many of these devices could be put into operation around the Earth, and in space, to observe the new spatial-flow physics, with special emphasis on correlation studies. These can be used to observe the spatial extent of the fluctuations. As well space-probe based systems could observe special effects in the flow pattern associated with the Earth-Moon system; these effects are caused by the α -dependent dynamics in (26).

4.4 Results from the Flinders detector

Results from the detector are shown in Fig. 15. There the time variations in picoseconds are plotted against local Adelaide time. The times have an arbitrary zero offset. However most significantly we see ~ 24 hr variations in the travel time, as also seen by De Witte. We also see variations in the times and magnitudes from day to day and within each day. These are the wave effects although as well a component of these is probably also coming from temperature change

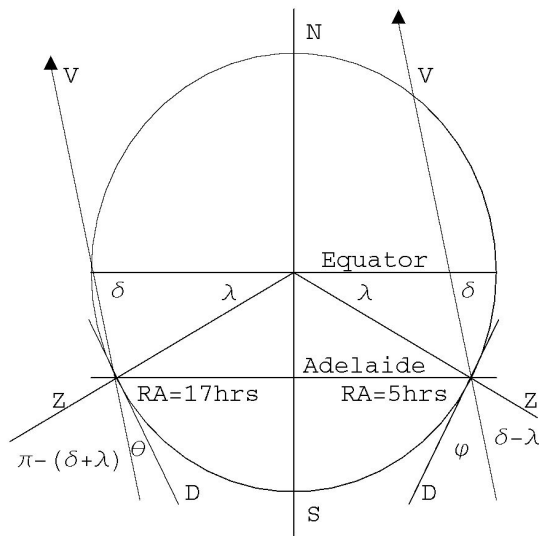


Fig. 16: Profile of Earth, showing NS axis, at Adelaide local sidereal time of $RA \approx 5$ hrs (on RHS) and at $RA \approx 17$ hrs (on LHS). Adelaide has latitude $\lambda = 38^\circ$ S. Z is the local zenith, and the detector arm has horizontal local NS direction D . The flow of space past the Earth has average velocity \mathbf{v} . The average direction, $-\mathbf{v}$, of motion of the Earth through local 3-space has $RA \approx 5$ hrs and Declination $\delta \approx 70^\circ$ S. The angle of inclination of the detector arm D to the direction $-\mathbf{v}$ is $\phi = \frac{\pi}{2} - \delta + \lambda$ and $\theta = \delta + \lambda - \frac{\pi}{2}$ at these two RA, respectively. As the Earth rotates the inclination angle changes from a minimum of θ to a maximum of ϕ , which causes the dominant “dip” effect in, say, Fig. 17. The gravitational wave effect is the change of direction and magnitude of the flow velocity \mathbf{v} , which causes the fluctuations in, say, Fig. 17. The latitude of Mt. Wilson is 34° N, and so its latitude almost mirrors that of Adelaide. This is relevant to the comparison in Fig. 18.

effects in the optical fibre transceivers. In time the instrument will be improved and optimised. But we are certainly seeing the evidence of absolute motion, namely the detection of the velocity field, as well as fluctuations in that velocity. To understand the daily variations we show in Fig. 16 the orientation of the detector arm relative to the Earth rotation axis and the Miller flow direction, at two key local sidereal times. So we now have a very inexpensive gravitational wave detector sufficiently small that even a coaxial-cable three-arm detector could easily be located within a building. Three orthogonal arms permit a complete measurement of the spatial flow velocity. Operating such a device over a year or so will permit the extraction of the Sun in-flow component and the Earth in-flow component, as well as a detailed study of the wave effects.

4.5 Right ascension

The sidereal effect has been well established, as shown in Fig. 9 for both the De Witte and Flinders data. Fig. 6 clearly shows that effect also for the Miller data. None of the other anisotropy experiments took data for a sufficiently long

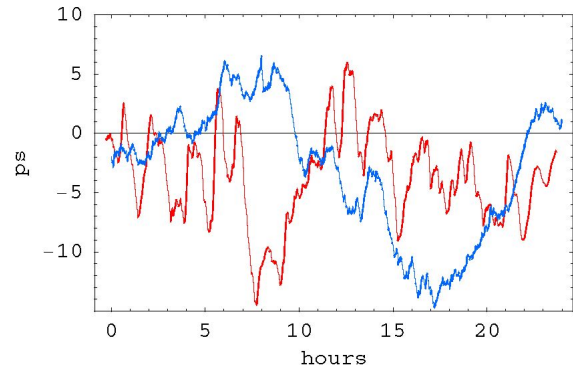


Fig. 17: The superimposed plots show the sidereal time effect. The plot (blue) with the minimum at approximately 17hrs local Adelaide time is from June 9, 2006, while the plot (red) with the minimum at approximately 8hrs local time is from August 23, 2006. We see that the minimum has moved forward in time by approximately 9 hrs. The expected shift for this 65 day difference, assuming no wave effects, is 4.3 hrs, but the wave effects shift the RA by some ± 2 hrs on each day as also shown in Fig. 9. This sidereal time shift is a critical test for the confirmation of the detector. Miller also detected variations of that magnitude as shown in Fig. 6. The August 23 data is also shown in Fig. 18, but there plotted against local sidereal time for comparison with the De Witte and Miller data.

enough time to demonstrate this effect, although their results are consistent with the Right Ascension and Declination found by the Miller, De Witte and Flinders experiments. From some 25 days of data in August 2006, the local Adelaide time for the largest travel-time difference is approximately 10 ± 2 hrs. This corresponds to a local sidereal time of 17.5 ± 2 hrs. According to the Miller convention we give the direction of the velocity vector of the Earth’s motion through the space, which then has Right Ascension 5.5 ± 2 hrs. This agrees remarkably well with the Miller and De Witte Right Ascension determinations, as discussed above. A one hour change in RA corresponds to a 15° change in direction at the equator. However because the declination, to be determined next, is as large as some 70° , the actual RA variation of ± 2 hrs, corresponds to an angle variation of some $\pm 10^\circ$ at that declination. On occasions there was no discernible unique maximum travel time difference; this happens when the declination is fluctuating near 90° , for then the RA becomes ill-defined.

4.6 Declination and speed

Because the prototype detector has only one arm, rather than the ideal case of three orthogonal arms, to determine the declination and speed we assume here that the flow is uniform and time-independent, and use the changing difference in travel times between the two main coaxial cables. Consider Fig. 11 showing the detector schematic layout and Fig. 16

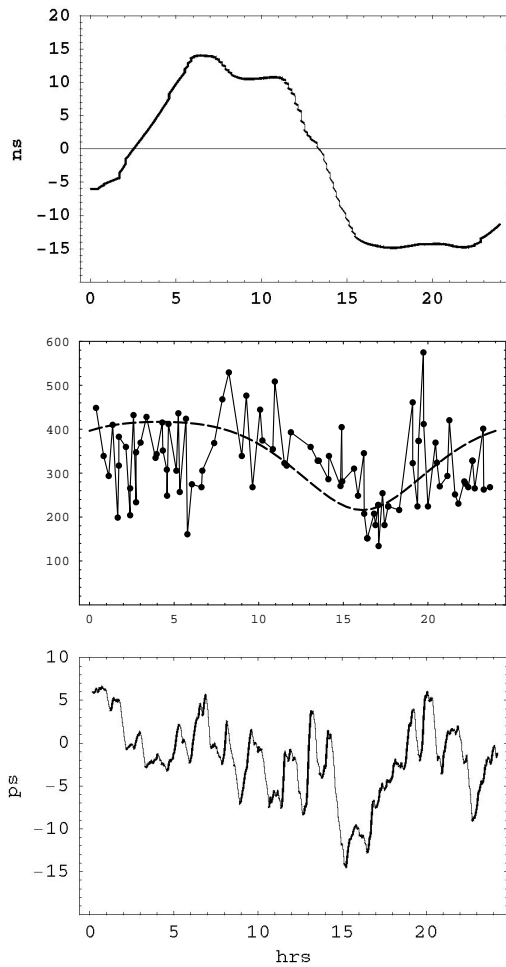


Fig. 18: **Top:** De Witte data, with sign reversed, from the first sidereal day in Fig. 8. This data gives a speed of approximately 430km/s. The data appears to have been averaged over more than 1hr, but still shows wave effects. **Middle:** Absolute projected speeds v_P in the Miller experiment plotted against sidereal time in hours for a composite day collected over a number of days in September 1925. Speed data like this comes from the fits as in Fig. 5 using the Special Relativity calibration in (20). Maximum projected speed is 417 km/s, as given in [3, 20, 9]. The data shows considerable fluctuations. The dashed curve shows the non-fluctuating variation expected over one day as the Earth rotates, causing the projection onto the plane of the interferometer of the velocity of the average direction of the space flow to change. If the data was plotted against solar time the form is shifted by many hours. Note that the min/max occur at approximately 5 hrs and 17 hrs, as also seen by De Witte and the new experiment herein. The corresponding variation of the azimuthal phase ψ from Fig. 5 is shown in Fig. 6. **Bottom:** Data from the new experiment for one sidereal day on approximately August 23. We see similar variation with sidereal time, and also similar wave structure. This data has been averaged over a running 1hr time interval to more closely match the time resolution of the Miller experiment. These fluctuations are believed to be real wave phenomena, predicted by the new theory of space [1]. The new experiment gives a speed of 418 km/s. We see remarkable agreement between all three experiments.

showing the various angles. The travel time in one of the circuits is given by

$$t_1 = \tau_1 + \frac{L_1}{v_c - v \cos(\Phi)} \tag{21}$$

and that in the other arm by

$$t_2 = \tau_1 + \frac{L_1}{v_c + v \cos(\Phi)} \tag{22}$$

where Φ is the angle between the detector direction and the flow velocity \mathbf{v} , v_c is the speed of radio frequency (RF) electromagnetic waves in the fibre when $\mathbf{v} = 0$, namely $v_c = c/n$ where n is the refractive index of the dielectric in the coaxial cable, and v is the change in that speed caused by the absolute motion of the coaxial cables through space, when the cable is parallel to \mathbf{v} . The factor of $\cos(\Phi)$ is just the projection of \mathbf{v} onto the cable direction. The difference in signs in (21) and (22) arises from the RF waves travelling in opposite directions in the two main coaxial cables. The distance L_1 is the arm length of the coaxial cable from A to B, and L_2 is that from C to D. The constant times τ_1 and τ_2 are travel times arising from the optical fibres, the converters, and the coaxial cable lengths not included in L_1 and L_2 , particularly the optical fibre travel times, which is the key to the new detector. The effect of the two shorter coaxial cable sections in each arm are included in τ_1 and τ_2 because the absolute motion effects from these arms is additive, as the RF travels in opposite directions through them, and so only contributes at 2nd order.

Now the experiment involves first the measurement of the difference $\Delta t = t_1 - t_2$, giving

$$\begin{aligned} \Delta t &= \tau_1 - \tau_2 + \frac{L_1}{v_c - v \cos(\Phi)} - \frac{L_2}{v_c + v \cos(\Phi)} \approx \\ &\approx \Delta\tau + (L_1 + L_2) \cos(\Phi) \frac{v}{v_c^2} + \dots \end{aligned} \tag{23}$$

on expanding to lowest order in v/v_c , and where $\Delta\tau \equiv \tau_1 - \tau_2 + \frac{L_1 - L_2}{v_c}$. Eqn. (23) is the key to the operation of the detector. We see that the effective arm length is $L = L_1 + L_2 = 10$ m. Over time the velocity vector \mathbf{v} changes, caused by the wave effects and also by the Earth's orbital velocity about the Sun changing direction, and as well the Earth rotates on its axis. Both of these effects cause v and the angle Φ to change. However over a period of a day and ignoring wave effects we can assume that v is unchanging. Then we can determine a declination δ and the speed v by (i) measuring the maximum and minimum values of Δt over a day, which occur approximately 12 hours apart, and (ii) determine $\Delta\tau$, which is the time difference when $v = 0$, and this is easily measured by putting the detector arm into a circular loop, as shown in Fig. 13, so that absolute motion effects cancel, at least to 1st order in v/v_c . Now from Fig. 16 we see that the maximum travel time difference Δt_{max} occurs

when $\Phi = \theta = \lambda + \delta - \frac{\pi}{2}$ in (23), and the minimum Δt_{min} when $\Phi = \phi = \lambda - \delta + \frac{\pi}{2}$, 12 hours later. Then the declination δ may be determined by numerically solving the transcendental equation which follows from these two times from (23)

$$\frac{\cos(\lambda + \delta - \frac{\pi}{2})}{\cos(\lambda - \delta + \frac{\pi}{2})} = \frac{\Delta t_{max} - \Delta\tau}{\Delta t_{min} - \Delta\tau}. \quad (24)$$

Subsequently the speed v is obtained from

$$v = \frac{(\Delta t_{max} - \Delta t_{min}) v_c^2}{L (\cos(\lambda + \delta - \frac{\pi}{2}) - \cos(\lambda - \delta + \frac{\pi}{2}))}. \quad (25)$$

In Fig. 14 we show the travel time variations for September 19, 2006. The detector arm was formed into a loop at approximately 10:00 hrs local time, with the system still operating: time averaging causes the trace to interpolate during this procedure, as shown. This looping effect is equivalent to having $\mathbf{v} = 0$, which defines the value of $\Delta\tau$. In plotting the times in Fig. 14 the zero time is set so that then $\Delta\tau = 0$. When the arms are straight, as before 10:00 hrs we see that on average the travel times are some 55 ps different: this is because the RF wave travelling S to N is now faster than the RF wave travelling from N to S. The times are negative because the longer S to N time is subtracted from the shorter N to S travel time in the DSO. As well we see the daily variation as the Earth rotates, showing in particular the maximum effect at approximately 8:00 hrs local time (approximately 15hrs sidereal time) as shown for the three experiments in Fig. 18, as well as wave and converter noise. The trace after 10:00 hrs should be flat – but the variations seen are coming from noise effects in the converters as well as some small signal arising from the loop not being formed into a perfect circle. Taking $\Delta t_{max} = -63$ ps and $\Delta t_{min} = -40$ ps from Fig. 14, (24) and (25) give $\delta = 72^\circ$ S and $v = 418$ km/s. This is in extraordinary agreement with the Miller results for September 1925.

We can also analyse the De Witte data. We have $L = 3.0$ km, $v_c = 200,000$ km/s, from Fig. 8 $\Delta t_{max} - \Delta t_{min} \approx 25$ ns, and the latitude of Brussels is $\lambda = 51^\circ$ N. There is not sufficient De Witte data to determine the declination of \mathbf{v} on the days when the data was taken. Miller found that the declination varied from approximately 60° S to 80° S, depending on the month. The dates for the De Witte data in Fig. 8 are not known but, for example, a declination of $\delta = 60^\circ$ gives $v = 430$ km/s.

4.7 Gravity and gravitational waves

We have seen that as well as the effect of the Earth rotation relative to the stars, as previously shown by the data from Michelson-Morley, Illingworth, Joos, Jaseja *et al.*, Torr and Kolen, Miller, and De Witte and the data from the new experiment herein, there is also from the experimental data of Michelson-Morley, Miller, Torr and Kolen, De Witte and from the new experiment, evidence of turbulence in this

flow of space past the Earth. This all points to the flow velocity field $\mathbf{v}(\mathbf{r}, t)$ having a time dependence over an above that caused simply because observations are taken from the rotating Earth. As we shall now show this turbulence is what is conventionally called “gravitational waves”, as already noted [1, 19, 20]. To do this we briefly review the new dynamical theory of 3-space, following [25], although it has been extensively discussed in the related literature. In the limit of zero vorticity for $\mathbf{v}(\mathbf{r}, t)$ its dynamics is determined by

$$\nabla \cdot \left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} \right) + \frac{\alpha}{8} ((\text{tr} D)^2 - \text{tr}(D^2)) = -4\pi G \rho, \quad (26)$$

where ρ is the effective matter/energy density, and where

$$D_{ij} = \frac{1}{2} \left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i} \right). \quad (27)$$

Most significantly data from the bore hole g anomaly and from the systematics of galactic supermassive black hole shows that $\alpha \approx 1/137$ is the fine structure constant known from quantum theory [21–24]. Now the Dirac equation uniquely couples to this dynamical 3-space, according to [25]

$$i\hbar \frac{\partial \psi}{\partial t} = -i\hbar \left(c\bar{\alpha} \cdot \nabla + \mathbf{v} \cdot \nabla + \frac{1}{2} \nabla \cdot \mathbf{v} \right) \psi + \beta m c^2 \psi \quad (28)$$

where $\bar{\alpha}$ and β are the usual Dirac matrices. We can compute the acceleration of a localised spinor wave packet according to

$$\mathbf{g} \equiv \frac{d^2}{dt^2} (\psi(t), \mathbf{r} \psi(t)) \quad (29)$$

With $\mathbf{v}_R = \mathbf{v}_0 - \mathbf{v}$ the velocity of the wave packet relative to the local space, as \mathbf{v}_0 is the velocity relative to the embedding space*, and we obtain

$$\mathbf{g} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} + (\nabla \times \mathbf{v}) \times \mathbf{v}_R - \frac{\mathbf{v}_R}{1 - \frac{v_R^2}{c^2}} \frac{1}{2} \frac{d}{dt} \left(\frac{v_R^2}{c^2} \right) \quad (30)$$

which gives the acceleration of quantum matter caused by the inhomogeneities and time-dependencies of $\mathbf{v}(\mathbf{r}, t)$. It has a term which limits the speed of the wave packet relative to space to be $< c$. Hence we see that the phenomenon of gravity, including the Equivalence Principle, has been derived from a deeper theory. Apart from the vorticity[†] and relativistic terms in (30) the quantum matter acceleration is the same as that of the structured 3-space [25, 8].

We can now show how this leads to both the spacetime mathematical construct and that the geodesic for matter worldlines in that spacetime is equivalent to trajectories from (30). First we note that (30) may be obtained by extremising the time-dilated elapsed time

$$\tau[\mathbf{r}_0] = \int dt \left(1 - \frac{v_R^2}{c^2} \right)^{1/2} \quad (31)$$

*See [25] for a detailed explanation of the embedding space concept.

[†]The vorticity term explains the Lense-Thirring effect [30].

with respect to the particle trajectory $\mathbf{r}_0(t)$ [1]. This happens because of the Fermat least-time effect for waves: only along the minimal time trajectory do the quantum waves remain in phase under small variations of the path. This again emphasises that gravity is a quantum wave effect. We now introduce a spacetime mathematical construct according to the metric

$$ds^2 = dt^2 - \frac{(\mathbf{dr} - \mathbf{v}(\mathbf{r}, t) dt)^2}{c^2} = g_{\mu\nu} dx^\mu dx^\nu. \quad (32)$$

Then according to this metric the elapsed time in (31) is

$$\tau = \int dt \sqrt{g_{\mu\nu} \frac{dx^\mu}{dt} \frac{dx^\nu}{dt}}, \quad (33)$$

and the minimisation of (33) leads to the geodesics of the spacetime, which are thus equivalent to the trajectories from (31), namely (30). Hence by coupling the Dirac spinor dynamics to the space dynamics we derive the geodesic formalism of General Relativity as a quantum effect, but without reference to the Hilbert-Einstein equations for the induced metric. Indeed in general the metric of this induced spacetime will not satisfy these equations as the dynamical space involves the α -dependent dynamics, and α is missing from GR*.

Hence so far we have reviewed the new theory of gravity as it emerges within the new physics[†]. In explaining gravity we discover that the Newtonian theory is actually flawed: this happened because the motion of planets in the solar system is too special to have permitted Newtonian to model all aspects of the phenomenon of gravity, including that the fundamental dynamical variable is a velocity field and not an acceleration field.

We now discuss the phenomenon of the so-called “gravitational waves”. It may be shown that the metric in (32) satisfies the Hilbert-Einstein GR equations, in “empty” space, but *only* when $\alpha \rightarrow 0$:

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} = 0, \quad (34)$$

where $G_{\mu\nu}$ is the Einstein tensor, $R_{\mu\nu} = R^\alpha_{\mu\alpha\nu}$ and $R = g^{\mu\nu} R_{\mu\nu}$ and $g^{\mu\nu}$ is the matrix inverse of $g_{\mu\nu}$, and the curvature tensor is

$$R^\rho_{\mu\sigma\nu} = \Gamma^\rho_{\mu\nu,\sigma} - \Gamma^\rho_{\mu\sigma,\nu} + \Gamma^\rho_{\alpha\sigma} \Gamma^\alpha_{\mu\nu} - \Gamma^\rho_{\alpha\nu} \Gamma^\alpha_{\mu\sigma}, \quad (35)$$

where $\Gamma^\alpha_{\mu\sigma}$ is the affine connection

$$\Gamma^\alpha_{\mu\sigma} = \frac{1}{2} g^{\alpha\nu} \left(\frac{\partial g_{\nu\mu}}{\partial x^\sigma} + \frac{\partial g_{\nu\sigma}}{\partial x^\mu} - \frac{\partial g_{\mu\sigma}}{\partial x^\nu} \right). \quad (36)$$

Hence the GR formalism fails on two grounds: (i) it does not include the spatial self-interaction dynamics which has

*Why the Schwarzschild metric, nevertheless, works is explained in [25].

[†]Elsewhere it has been shown that this theory of gravity explains the bore hole anomaly, supermassive black hole systematics, the “dark matter” spiral galaxy rotation anomaly effect, as well as the putative successes of GR, including light bending and gravitational lensing.

coupling constant α , and (ii) it very effectively obscures the dynamics, for the GR formalism has spuriously introduced the speed of light when it is completely absent from (26), except on the RHS when the matter has speed near that of c relative to the space[‡]. Now when wave effects are supposedly extracted from (34), by perturbatively expanding about a background metric, the standard derivation supposedly leads to waves with speed c . This derivation must be manifestly incorrect, as the underlying equation (26), even in the limit $\alpha \rightarrow 0$, does not even contain c . In fact an analysis of (26) shows that the perturbative wave effects are fluctuations of $\mathbf{v}(\mathbf{r}, t)$, and travel at approximately that speed, which in the case of the data reported here is some 400 km/s in the case of earth based detections, i. e. 0.1% of c . These waves also generate gravitational effects, but only because of the α -dependent dynamical effects: when $\alpha \rightarrow 0$ we still have wave effects in the velocity field, but that they produce no gravitational acceleration effects upon quantum matter. Of course even in the case of $\alpha \rightarrow 0$ the velocity field wave effects are detectable by their effects upon EM radiation, as shown by various gas-mode Michelson interferometer and coaxial cable experiments. Amazingly there is evidence that Michelson-Morley actually detected such gravitational waves as well as the absolute motion effect in 1887, because fluctuations from day to day of their data shows effects similar to those reported by Miller, Torr and Kolen, De Witte, and the new experiment herein. Of course if the Michelson interferometer is operated in vacuum mode it is totally insensitive to absolute motion effects and to the accompanying wave effects, as is the case. This implies that experiments such as the long baseline terrestrial Michelson interferometers are seriously technically flawed as gravitational wave detectors. However as well as the various successful experimental techniques discussed herein for detecting absolute motion and gravitational wave effects a novel technique is that these effects will manifest in the gyroscope precessions observed by the Gravity Probe B satellite experiment [30, 31].

Eqn. (26) determines the dynamical time evolution of the velocity field. However that aspect is more apparent if we write that equation in the integro-differential form

$$\frac{\partial \mathbf{v}}{\partial t} = -\nabla \left(\frac{\mathbf{v}^2}{2} \right) + G \int d^3 r' \frac{\rho_{DM}(\mathbf{r}', t) + \rho(\mathbf{r}', t)}{|\mathbf{r} - \mathbf{r}'|^3} (\mathbf{r} - \mathbf{r}') \quad (37)$$

in which ρ_{DM} is velocity dependent,

$$\rho_{DM}(\mathbf{r}, t) \equiv \frac{\alpha}{32\pi G} ((\text{tr} D)^2 - \text{tr}(D^2)), \quad (38)$$

and is the effective “dark matter” density. This shows several key aspects: (i) there is a local cause for the time de-

[‡]See [1] for a possible generalisation to include vorticity effects and matter related relativistic effects.

pendence from the ∇ term, and (ii) a non-local action-at-a-distance effect from the ρ_{DM} and ρ terms. This is caused by space being essentially a quantum system, so this is better understood as a quantum non-local effect. However (37) raises the question of where the observed wave effects come from? Are they local effects or are they manifestations of distant phenomena? In the latter case we have a new astronomical window on the universe.

5 Conclusions

We now have eight experiments that independently and consistently demonstrated (i) the anisotropy of the speed of light, and where the anisotropy is quite large, namely $300,000 \pm 420$ km/s, depending on the direction of measurement relative to the Milky Way, (ii) that the direction, given by the Right Ascension and Declination, is now known, being established by the Miller, De Witte and Flinders experiments*. The reality of the cosmological meaning of the speed was confirmed by detecting the sidereal time shift over 6 months and more, (iii) that the relativistic Fitzgerald-Lorentz length contraction is a real effect, for otherwise the results from the gas-mode interferometers would have not agreed with those from the coaxial cable experiments, (iv) that Newtonian physics gives the wrong calibration for the Michelson interferometer, which of course is not surprising, (v) that the observed anisotropy means that these eight experiments have detected the existence of a 3-space, (vi) that the motion of that 3-space past the Earth displays wave effects at the level of ± 30 km/s, as confirmed by three experiments, and possibly present even in the Michelson-Morley data.

The Miller experiment was one of the most significant experiments of the 20th century. It meant that a substructure to reality deeper than spacetime had been revealed, that spacetime was merely a mathematical construct and not an aspect of reality. It meant that the Einstein postulate regarding the invariance of the speed of light was incorrect — in disagreement with experiment, and had been so from the beginning. This meant that the Special Relativity effects required a different explanation, and indeed Lorentz had supplied that some 100 years ago: in this it is the absolute motion of systems through the dynamical 3-space that causes SR effects, and which is diametrically opposite to the Einstein formalism. This has required the generalisation of the Maxwell equations, as first proposed by Hertz in 1888 [26]), the Schrödinger and Dirac equations [25, 8]. This in turn has led to a derivation of the phenomenon of gravity, namely that it is caused by the refraction of quantum waves by the inhomogeneities and time dependence of the flowing patterns within space. That same data has also revealed the in-flow component of space past the Earth towards the Sun

*Intriguingly this direction is, on average, perpendicular to the plane of the ecliptic. This may be a dynamical consequence of the new theory of space.

[1], and which also is revealed by the light bending effect observed by light passing close to the Sun's surface [25]. This theory of gravity has in turn led to an explanation of the so-called "dark matter" effect in spiral galaxies [22], and to the systematics of black hole masses in spherical star systems [25], and to the explanation of the bore hole g anomaly [21, 22, 23]. These effects have permitted the development of the minimal dynamics of the 3-space, leading to the discovery that the parameter that determines the strength of the spatial self-interaction is none other than the fine structure constant, so hinting at a grand unification of space and the quantum theory, along the lines proposed in [1], as an *information theoretic* theory of reality.

These developments demonstrate the enormous significance of the Miller experiment, and the extraordinary degree to which Miller went in testing and refining his interferometer. The author is proud to be extending the Miller discoveries by studying in detail the wave effects that are so apparent in his extensive data set. His work demonstrates the enormous importance of doing novel experiments and doing them well, despite the prevailing prejudices. It was a tragedy and an injustice that Miller was not recognised for his contributions to physics in his own lifetime; but not everyone is as careful and fastidious with detail as he was. He was ignored by the physics community simply because in his era it was believed, as it is now, that absolute motion was incompatible with special relativistic effects, and so it was accepted, without any evidence, that his experiments were wrong. His experiences showed yet again that few in physics actually accept that it is an evidence based science, as Galileo long ago discovered also to his great cost. For more than 70 years this experiment has been ignored, until recently, but even now discussion of this and related experiments attracts hostile reaction from the physics community.

The developments reported herein have enormous significance for fundamental physics — essentially the whole paradigm of 20th century physics collapses. In particular spacetime is now seen to be no more than a mathematical construct, that no such union of space and time was ever mandated by experiment. The putative successes of Special Relativity can be accommodated by the reality of a dynamical 3-space, with time a distinctly different phenomenon. But motion of quantum and even classical electromagnetic fields through that dynamical space explain the SR effects. Lorentz symmetry remains valid, but must be understood as applying only when the space and time coordinates are those arrived at by the Einstein measurement protocol, and which amounts to not making corrections for the effects of absolute motion upon rods and clocks on those measurements. Nevertheless such coordinates may be used so long as we understand that they lead to a confusion of various related effects. To correct the Einstein measurement protocol readings one needs only to have each observer use an absolute motion meter, such as the new compact all-optical devices, as well as a rod and

clock. The fundamental discovery is that for some 100 years physics has failed to realise that a dynamical 3-space exists — it is observable. This contradicts two previous assumptions about space: Newton asserted that it existed, was unchanging, but not observable, whereas Einstein asserted that 3-space did not exist, could not exist, and so clearly must be unobservable. The minimal dynamics for this 3-space is now known, and it immediately explains such effects as the “dark matter” spiral galaxy rotation anomaly, novel black holes with non-inverse square law gravitational accelerations, which would appear to offer an explanation for the precocious formation of spiral galaxies, the bore hole anomaly and the systematics of supermassive black holes, and so on. Dramatically various pieces of data show that the self-interaction constant for space is the fine structure constant. However unlike SR, GR turns out to be flawed but only because it assumed the correctness of Newtonian gravity. The self-interaction effects for space make that theory invalid even in the non-relativistic regime — the famous universal inverse square law of Newtonian gravity is of limited validity. Uniquely linking the quantum theory of matter with the dynamical space shows that gravity is a quantum matter wave effect, so we can’t understand gravity without the quantum theory. As well the dynamics of space is intrinsically non-local, which implies a connectivity of reality that far exceeds any previous notions.

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References

- Cahill R. T. Process Physics: From information theory to quantum space and matter. Nova Science, N.Y., 2005.
- Cahill R. T. and Kitto K. Michelson-Morley experiments revisited. *Apeiron*, 2003, v. 10(2), 104–117.
- Michelson A. A. and Morley E. W. *Philos. Mag.*, S. 5, 1887, v. 24, No. 151, 449–463.
- Miller D. C. *Rev. Mod. Phys.*, 1933, v. 5, 203–242.
- Cahill R. T. Process Physics and Whitehead: the new science of space and time. Whitehead 2006 Conference, Salzburg, to be pub. in proceedings, 2006.
- Cahill R. T. Process Physics: self-referential information and experiential reality. *To be pub.*
- Müller H. *et al.* Modern Michelson-Morley experiment using cryogenic optical resonators. *Phys. Rev. Lett.*, 2003, v. 91(2), 020401-1.
- Cahill R. T. Dynamical fractal 3-space and the generalised Schrödinger equation: Equivalence Principle and vorticity effects. *Progress in Physics*, 2006, v. 1, 27–34.
- Cahill R. T. The Roland DeWitte 1991 experiment. *Progress in Physics*, 2006, v. 3, 60–65.
- Torr D. G. and Kolen P. *Precision Measurements and Fundamental Constants*, ed. by Taylor B. N. and Phillips W. D. Nat. Bur. Stand. (U.S.), Spec. Pub., 1984, v. 617, 675–679.
- Illingworth K. K. *Phys. Rev.*, 1927, v. 3, 692–696.
- Joos G. *Ann. der Physik*, 1930, Bd. 7, 385.
- Jaseja T. S. *et al.* *Phys. Rev.*, v. A133, 1964, 1221.
- Cahill R. T. The Michelson and Morley 1887 experiment and the discovery of absolute motion. *Progress in Physics*, 2005, v. 3, 25–29.
- Cahill R. T. The Michelson and Morley 1887 experiment and the discovery of 3-space and absolute motion. *Australian Physics*, Jan/Feb 2006, v. 46, 196–202.
- Cahill R. T. The detection of absolute motion: from 1887 to 2005. *NPA Proceedings*, 2005, 12–16.
- Cahill R. T. The speed of light and the Einstein legacy: 1905–2005. *Infinite Energy*, 2005, v. 10(60), 28–27.
- Cahill R. T. The Einstein postulates 1905–2005: a critical review of the evidence. In: *Einstein and Poincaré: the Physical Vacuum*, Dvoeglazov V. V. (ed.), Apeiron Publ., 2006.
- Cahill R. T. Quantum foam, gravity and gravitational waves. arXiv: physics/0312082.
- Cahill R. T. Absolute motion and gravitational effects. *Apeiron*, 2004, v. 11(1), 53–111.
- Cahill R. T. Gravity, “dark matter” and the fine structure constant. *Apeiron*, 2005, v. 12(2), 144–177.
- Cahill R. T. “Dark matter” as a quantum foam in-flow effect. In: *Trends in Dark Matter Research*, ed. J. Val Blain, Nova Science, N.Y., 2005, 96–140.
- Cahill R. T. 3-Space in-flow theory of gravity: Boreholes, blackholes and the fine structure constant. *Progress in Physics*, 2006, v. 2, 9–16.
- Cahill R. T. Black holes in elliptical and spiral galaxies and in globular clusters. *Progress in Physics*, 2005, v. 3, 51–56.
- Cahill R. T. Black holes and quantum theory: the fine structure constant connection. *Progress in Physics*, 2006, v. 4, 44–50.
- Hertz H. On the fundamental equations of electro-magnetics for bodies in motion. *Wiedemann’s Ann.*, 1890, v. 41, 369; *Electric waves*, collection of scientific papers. Dover, N.Y., 1962.
- Fitzgerald G. F. *Science*, 1889, v. 13, 420.
- Lorentz H. A. Electric phenomena in a system moving with any velocity less than that of light. In *The Principle of Relativity*, Dover, N.Y., 1952.
- Hicks W. M. On the Michelson-Morley experiment relating to the drift of the ether. *Phil. Mag.*, 1902, v. 3, 9–42.
- Cahill R. T. Novel Gravity Probe B frame-dragging effect. *Progress in Physics*, 2005, v. 3, 30–33.
- Cahill R. T. Novel Gravity Probe B gravitational wave detection. arXiv: physics/0408097.