Re-Analysis of the Marinov Light-Speed Anisotropy Experiment

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The anisotropy of the speed of light at 1 part in $10^3$ has been detected by Michelson and Morley (1887), Miller (1925/26), Illingworth (1927), Joos (1930), Jaseja et al. (1964), Torr and Kolen (1984), De Witte (1991) and Cahill (2006) using a variety of experimental techniques, from gas-mode Michelson interferometers (with the relativistic theory for these only determined in 2002) to one-way RF coaxial cable propagation timing. All agree on the speed, right ascension and declination of the anisotropy velocity. The Stephan Marinov experiment (1984) detected a light speed anisotropy using a mechanical coupled shutters technique which has holes in co-rotating disks, essentially a one-way version of the Fizeau mechanical round-trip speed-of-light experiment. The Marinov data is re-analysed herein because the velocity vector he determined is in a very different direction to that from the above experiments. No explanation for this difference has been uncovered.

1 Introduction

That the speed of light in vacuum is the same in all directions, i.e. isotropic, for all observers has been taken as a critical assumption in the standard formulation of fundamental physics, and was introduced by Einstein in 1905 as one of his key postulates when formulating his interpretation of Special Relativity. The need to detect any anisotropy has challenged physicists from the 19th century to the present day, particularly following the Michelson-Morley experiment of 1887. The problem arose when Maxwell in 1861 successfully computed the speed of light $c$ from his unified theory of electric and magnetic fields: but what was the speed $c$ relative to? There have been many attempts to detect any supposed light-speed anisotropy, and as discussed in the Sect.2 there have so far been 8 successful and consistent such experiments, and as well numerous unsuccessful experiments, i.e. experiments in which no anisotropy was observed. The reasons for these different outcomes is now understood: any light-speed anisotropy produces not only an expected ‘direct’ effect, being that which is expected to produce a ‘signal’, but also affects the very physical structure of the apparatus, and with this effect usually overlooked in the design of some detectors. In some designs these effects exactly cancel.

The key point here is not whether the predicted Special Relativity effects are valid or invalid, for the experimental evidence is overwhelming that these predictions are valid, but rather whether the Lorentz or Einstein interpretation of Special Relativity is correct. This debate has always been confused by the failure to understand that the successes of Special Relativity, and its apparent deduction from the above Einstein postulate, does not actually require that the speed of light be invariant, as Fitzgerald and Lorentz pointed out over 100 years ago, see discussions in [1, 19]. Rather the issue is whether the Special Relativity effects are caused by absolute motion of systems through a dynamical 3-space, or whether we have no 3-space and only a four-dimensional spacetime. So the question is about whether or not the 3-space can be detected by means of the anisotropy of light, since in this interpretation the speed is $c$ only relative to this space locally. This comes down to the issue of whether 3-space or spacetime actually exists, not whether the local Special Relativity effects are valid or not.

As already stated there is overwhelming evidence from 8 experiments that the speed of light is anisotropic, and with a large anisotropy at the level of 1 part in $10^3$: so these experiments show that a dynamical 3-space exists, and that the spacetime concept was only a mathematical construct - it does not exist as an entity of reality, it has no ontological significance. These developments have lead to a new physics in which the dynamics of the 3-space have been formulated, together with the required generalisations of the Maxwell equations (as first suggested by Hertz in 1890 [3]), and of the Schrödinger and Dirac equations, which have lead to the new emergent theory and explanation of gravity, with numerous confirmations of that theory from the data from...
black hole systematics, light bending, spiral galaxy rotation anomalies, bore hole anomalies, etc. This data has revealed that the coupling constant for the self-interaction of the dynamical 3-space is none other than the fine structure constant \( \approx 1/137 \) \[9, 10, 11, 12\], which suggests an emerging unified theory of quantum matter and a quantum foam description of the dynamical 3-space.

The substance of this report is to re-examine a light-speed anisotropy experiment performed by Stefan Marinov in Graz in 1984 using essentially separated mechanical light choppers in a special modified version of the original Fizeau technique - basically Marinov measured the difference in travel time between light beams travelling in opposite directions \[3\]. However there is an apparent problem with the anisotropy velocity vector that Marinov reported, namely it had a very different direction, and also a somewhat different speed, from that which has recently been determined from the 8 experiments discussed in Sect.2. However we conclude that no explanation has been found for why the Marinov velocity vector is so different from that determined by the 8 other experiments.

It is truly amazing that for over 100 year physics has failed to acknowledge the anisotropy of the light speed; and a very large effect of the order of 1 part in \(10^3\). This is partly explained by the fact that any discussion of these experiments and the implications is banned from mainstream physics. This apparently follows from the long-standing misconception that the successes of Special Relativity, and of Lorentz symmetry, require that no such anisotropy exists. Rather, the existence of a preferred direction, of an actual locally detected frame of reference, is perfectly consistent with Special Relativity and Local Lorentz Symmetry, although the explication of this is somewhat subtle, requiring a very careful operational definition of what is meant by the space and time coordinates in the different formalisms. Essentially the well-known Einstein formalism builds into the definitions of space and time coordinates that the speed of light is invariant. However such definitions, while permitted mathematically, do not correspond to the physical definition.

2 Brief History of Light Speed Anisotropy Measurements

The most famous and influential of the early attempts to detect any anisotropy in the speed of light was the Michelson-Morley experiment of 1887, \[2\]. Despite that, and its influence on physics, its operation was only finally understood in 2002 \[5, 6, 7\]. The problem has been that the Michelson interferometer has a major flaw in its design, when used to detect any light-speed anisotropy effect\[4\]. To see this requires use of Special Relativity effects. The Michelson interferometer compares the round-trip light travel time in two orthogonal arms, by means of interference fringe shifts measuring time differences, as the device is rotated. However if the device is operated in vacuum, any anticipated change in the total travel times caused by the light travelling at different speeds in the outward and inward directions is exactly cancelled by the Fitzgerald-Lorentz mirror-supporting-arm contraction effect - a real physical effect. Of course this is precisely how Fitzgerald and Lorentz independently arrived at the idea of the length contraction effect. In vacuum this means that the round-trip travel times in each arm do not change during rotation. This is the fatal design flaw that has confounded physics for over 100 years. However the cancellation of a supposed change in the round-trip travel times and the Lorentz contraction effect is merely an incidental flaw of the Michelson interferometer. The critical observation is that if we have a gas in the light path, the round-trip travel times are changed, but the Lorentz arm-length contraction effect is unchanged, and then these effects no longer exactly cancel. Not surprisingly the fringe shifts are now proportional to \(n^2 - 1\), where \(n\) is the refractive index of the gas. Of course with a gas present one must also take account of the Fresnel drag effect, because the gas itself is in absolute motion. This is an important effect, so large in fact that it reverses the sign of the time differences between the two arms, although in operation that is not a problem. As well, since for example for air \(n = 1.00029\) at STP, the sensitivity of the interferometer is very low. Nevertheless the Michelson-Morley experiment as well as the Miller Michelson interferometer experiment of 1925/1926 \[13\] were done in air, which is why they indeed observed and reported fringe shifts. As well Illingworth \[14\] and Joos \[15\] used helium gas in the light paths in their Michelson interferometers; taking account of that brings their results into agreement with those of the air interferometer experiment, and so confirming the refractive index effect. Jaseja et al. \[16\] used a He-Ne gas mixture of unknown refractive index, but again detected fringe shifts on rotation. A re-analysis of the data from the above experiments, particularly from the enormous data set of Miller, has revealed that a large light-speed anisotropy had been detected from the very beginning of such experiments, where the speed is

1Which also severely diminishes its use in long-baseline interferometers built to detect gravitational waves
Figure 1: Schematic diagram of the Marinov one-way speed-of-light apparatus using the “coupled shutters” technique. Two co-rotating disks have holes through which light passes. \( S \) is the light source, \( BS \) is a beam splitter, and various mirrors \( M \) direct the light though the holes. The light intensity is measured by the photocell detectors \( D \). Changes in the speed of light affect the amount of light that can pass through the distant hole.

some \( 430 \pm 20 \text{km/s} \) - this is in excess of 1 part in \( 10^3 \), and the Right Ascension and Declination of the direction was determined by Miller [13] long ago.

Curiously numerous experimentalists developed vacuum mode Michelson interferometers as vacuum pump technology became available, and of course the fringe shifts eventually went away, supposedly confirming that no light-speed anisotropy existed. However one must always be careful of so-called “null” experiments - it may actually be a “dud” experiment instead. In recent years the vacuum-mode interferometers have been ‘improved’ considerably by using small cryogenic vacuum-mode Fabry-Perot resonators, as for example Müller et al. [20]. Trying to get experimentalists to put some gas in at least one of the resonators, so that the gas effect enables the device to detect the anisotropy, has proven to be very challenging.

Another technique that has been successfully used is to measure the one-way travel time of RF waves in coaxial cables, as in Torr and Kolen 1981 [17] with the one-way travel through 500m of cable, De Witte 1991 [18] using travel time differences between two 1.5km cables, and Cahill 2006 [19] using two 5 meter cables facilitated by the optical fiber effect for orientation-invariant timing transfers. Over the years the problem of making very accurate timing measurements that are stable over days has evolved. Torr and Kolen and De Witte both used multiple atomic clocks, and long coaxial cables, while Cahill uses one atomic clock and the optical fiber effect. These experiments are discussed in [19]. In the DeWitte and Cahill experiments one measures the difference in travel time between RF waves travelling in opposite directions. The results from these 3 coaxial cable experiments and the earlier gas-mode Michelson interferometer experiments are in excellent agreement. Also as discussed in [19] the optical fiber effect permits the construction of very small 1st order in \( v/c \) interferometers without the gas \( n^2 - 1 \) effect, and these are extremely accurate and cheap. These differential one-way coaxial-cable time-difference experiments are analogous to the Marinov mechanical Coupled Shutter device, which we now finally discuss.

3 The Marinov Light-Speed Anisotropy Experiment

In 1984 Stephan Marinov performed in Graz a direct measurement of the variations in the one-way speed of light. This used the classic rotating shutters method where the speed of light is determined by observing

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2S. Dawkins and A. Luiten from the University of Western Australia have now done just that, putting \( N_2 \) gas into one arm. At the Australian Institute of Physics 17th Congress in Brisbane, Australia, in December 2006, they reported that beat frequency shifts, the analogue of fringe shifts, were now detected as the earth rotated - because of extremely good stability they don’t need to do short term rotations of the apparatus. Of course we must wait until they have optimised the apparatus and reported their results.
the light transmission intensity when it propagates through vacuum between small holes in separated but co-
rotating disks, as shown in Fig.1. The use of a mechanical timing method to determine the speed of light dates
back to Fizeau who in 1849 performed a round-trip speed-of-light measurement in which a beam of light was
reflected back from a mirror 8 km away, with the beam passing through the gaps between the teeth of a rapidly
rotating wheel. However there is an import development with the Marinov experiment: it is a one-way speed
measurement. As discussed above the round-trip time measurements cannot determine the one-way speed of
light, except under special circumstance, such as when the light propagates in a gas, as in gas-mode Michelson
interferometers and Fabry-Perot resonant cavities. However the Marinov experiment ideally measures the
time-difference between the travel-time in two opposite directions. The apparatus involved 2 co-rotating disks
separated by a distance of 120 cm. Light from an Argon laser was split and directed axially towards the disks
through small holes at a radius of 12 cm. Photocells detected the light when it passed through the holes in
the opposite disks, with the whole apparatus rotating at 200 rev/s, and with the axis aligned along the local
meridian, i.e. NS. The intensity of the light emerging from the holes in the disks depends on the light travel
time, and is determined by means of a galvanometer measuring the current from the silicon photodetectors.
More details are available in [4]. Fig.2 shows the current differences over the 5 days February 9-13. The data
clearly shows the expected time signature.

The geometry of the experiment is explained in Fig.3. The key effect is that the speed of light is $c$ relative
to the space flowing past the Earth with velocity $v$. This means that the speed of light relative to the axis of
the apparatus varies as the Earth rotates, as the angle between the flow and the detector light beams changes.
At the extremes the projected speeds are $v_a$ and $v_b$, and are given by

$$v_a = v \sin(\delta - \phi), \quad v_b = v \sin(\delta + \phi),$$

(1)

where $v = |v|$. However there is an important experimental aspect which must be taken into account, namely
that the two components of the apparatus, namely that part with the light travelling essentially N to S can
never be made identical to the part with the light travelling from S to N at the level of precision required
in this experiment. Marinov acknowledges this problem but in the end actually failed to come to the correct
method for dealing with it. Because of the asymmetry of the two parts of the experiment [1] must be put in
the form

$$v_a = v \sin(\delta - \phi) + V, \quad v_b = v \sin(\delta + \phi) + V$$

(2)

where now $v_a$ and $v_b$ are the speeds determined from the current measurements, and most importantly $V$ is
an effective speed that parametrizes the asymmetry in the apparatus: because even if the flow speed $v = 0$
the apparatus will register non-zero $v_a = v_b \neq 0$. The only way to determine $V$ is to rotate the apparatus
while the disks are spinning, from NS to SN orientation. Then this interchanges the two parts, and now the
$v_a$ and $v_b$ are given by (2), but now with $V \rightarrow -V$. Then one could compute $V$, and then the ‘zero speed’ of

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Figure 2: Measurements of photocell current differences, $\delta I$, from the Marinov “coupled-shutters” one-way light-
speed experiment in Graz, Austria, February 9-13, 1984, reproduced from [4]. The times in hours are local times. The
“null line” (i.e the abscissa) turns out to be arbitrary, as Marinov did not establish the value of the asymmetry speed
$V$ in (2) of the detector, and in fact incorrectly assumed that $V = 0$. 

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the apparatus is properly set. A similar task arose in the Cahill one-way RF coaxial cable experiment. There timing signals between the ends of the RF cables is facilitated by sending infrared signals through optical fibers for which the propagation times are invariant, unlike the RF in the coaxial cables. The cables cannot be cut to equal length with sufficient accuracy, and to set the ‘zero speed’ reading of the device, one could rotate the device through 180 degree, which causes the asymmetry effect to manifest with the opposite sign. However in this experiment another solution was available, namely to fold the cables into a circular loop. Then the effects of absolute motion cancels, and the ‘zero’ for the instrument is easily established. While Marinov was certainly aware of this asymmetry problem, in the end he effectively ignored it. In the re-analysis herein we do take account of this important problem. It means however that because the two equations in (2) now have three unknowns, \( v, \delta \) and \( V \), we cannot determine a unique solution. Marinov of course assumed that \( V = 0 \), which then permitted a unique but incorrect solution. Eliminating \( V \) from (2) we obtain

\[
\begin{align*}
\frac{v}{v_b} - \frac{v_a}{v_b} &= \sin(\delta + \phi) - \sin(\delta - \phi), \\
\end{align*}
\]

which at best gives us only a possible relationship between \( v \) and \( \delta \). In Fig.4 we show various \( v - \delta \) results from some five light-speed anisotropy experiments, as explained in the caption. These are remarkably consistent, taking into account that they vary over a year because of the changing velocity of the Earth about the sun. However the Miller and Torr-Kolen results are from February data, and are thus most relevant to the Marinov experiment. Marinov reported that from the data in Fig.2 he deduced that \( v_a = -342 \pm 30 \text{ km/s} \) and \( v_b = +143 \pm 30 \text{ km/s} \). However the resulting \( v - \delta \) plot is then almost exactly twice as large as the \( v - \delta \) values from the indicated experiments. It is possible that there is an error here in going from photodetector currents to the \( v_a \), and \( v_b \) speeds. So here I have taken \( v_a = (342 \pm 30)/2 \text{ km/s} \) and \( v_b = (+143 \pm 30)/2 \text{ km/s} \). These generate the curves in Fig.4. If we assume the value for \( v \) from the Miller and Torr-Kolen experiments of 430 km/s then we obtain a declination for \(-v\) of 68 \pm 4 degrees S, although the actual errors are probably larger. For this solution one can now extract the value of \( V \) from (2), and we obtain \( V = -228 \text{km/s} \), confirming that the asymmetry effect is significant. So one can conclude that, subject to the factor of two correction, the speed
and declination from the Marinov data is consistent with the other experiments. Ignoring the asymmetry speed V Marinov obtained a speed and declination for v of v = 362 ± 40 km/s, and δ = −24 ± 7 degrees, i.e. a declination for −v of δ = +24 ± 7 degrees.

Marinov reported a right ascension for v of α = 12.5h ± 1h, based upon the local times for the maximum and minimum in Fig.2 of 15h ± 1h and 3h ± 1h. Let us work through this determination. At midday on March 21 the local sidereal time at Greenwich is 0h. Graz has longitude 15h26′E, or 1 hour ahead of Greenwich. So the local time in Graz of 13h corresponds to a local sidereal time of +1h. The experiment was done in the period February 9-13, which is approximately 38 days before March 21, and so the local sidereal time was retarded by 2.5h, so that on February 11 at 13h in Graz the local sidereal time is −1.5h. Then the local time of 15h = 13h + 2h corresponds to a local sidereal time of α = 2h − 1.5h = 0.5h, and 3h = 13h − 10h corresponds to α = −10h − 1.5h = −11.5h ≡ 12.5h. Hence the right ascension of −v from the Marinov experiment is 0.5h ± 1h. This is to be compared to the right ascension of −v reported by Miller for February of 6h. Hence the Marinov data gives a right ascension for v of 12.5h which agrees with that reported by Marinov [4].
4 The Cosmic Microwave Background Anisotropy Velocity

The Cosmic Microwave Background (CMB) velocity is often confused with the Absolute Motion (AM) velocity or light-speed anisotropy velocity as determined in the experiments discussed herein. However these are totally unrelated and in fact point in very different directions, being almost at 90° to each other, with the CMB velocity being 369 km/s in direction ($\alpha = 11.2^h, \delta = -7.22^0$). The CMB velocity vector was first determined in 1977 by Smoot et al. [21] giving 390±60 km/s, ($\alpha = 11 \pm 0.6^h, \delta = 6 \pm 10^0$).

The CMB velocity is obtained by defining a frame of reference in which the thermalised CMB $3^0K$ radiation is isotropic, that is by removing the dipole component, and the CMB velocity is the velocity of the Earth in that frame. The CMB velocity is a measure of the motion of the solar system relative to the universe as a whole, or at least a spherical shell of the universe some 13 Gyrs in the past, and indeed the near uniformity of that radiation in all directions demonstrates that we may meaningfully refer to the spatial structure of the universe. The concept here is that at the time of decoupling of this radiation from matter that matter was on the whole, apart from small observable fluctuations, on average at rest with respect to the 3-space. So the CMB velocity is not motion with respect to the local 3-space now; that is the AM velocity. Contributions to the AM velocity would arise from the orbital motion of the solar system within the Milky Way galaxy, which has a speed of some 250 km/s, and contributions from the motion of the Milky Way within the local cluster, and so on to perhaps super clusters, as well as flows of space associated with gravity in the Milky Way and local galactic cluster etc. The difference between the CMB velocity and the AM velocity is explained by the spatial flows that are responsible for gravity at the galactic scales.

In a recent light-speed anisotropy experiment by Navia et al. [22] it was assumed in the analysis that the light speed anisotropy velocity (AM) is the same as the CMB velocity.

5 Conclusions

The re-analysis herein of the Marinov one-way light-speed anisotropy experiment has left unexplained why his anisotropy velocity is so different from that detected by 8 other experiments. However we note that it is quite similar to the anisotropy vector arising from the CMB detections. The observed light-speed anisotropy in all the experiments is very large being in excess of 1 part in $10^4$. This effect continues to be denied by mainstream physics, despite its detection involving at least 8 experiments extending over more than 100 years. What this effect shows is that reality involves a dynamical 3-space, as Lorentz suggested, and not a spacetime as Einstein suggested. Nevertheless, as discussed in [19], one can arrive at the spacetime as a well-defined mathematical construct, but which has no ontological significance. This means that the special relativity effects are caused by the actual absolute motion of systems through the 3-space as Lorentz long ago suggested. It also means that this 3-space is a dynamical system and the internal dynamics for this 3-space have already been determined [1], and which has lead to a new explanation for gravity, namely that it is caused by the refraction of either EM waves or quantum matter waves by the time dependence and inhomogeneities of the flow of the substructure of this 3-space. As discussed in [1, 19] many of these absolute motion experiments revealed fluctuations or turbulence in the velocity $v$, and these correspond to the gravitational waves. These wave effects occur in $v$ at the 20% level, so even they could be detected in a modern mechanical light chopper apparatus, although the new optical fiber technique is even simpler.

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References

[1] Cahill R.T. Process Physics: From Information Theory to Quantum Space and Matter, Nova Science Pub., New York, 2005.

[2] Michelson A.A. and Morley E.W. Philos. Mag. S.5 24 No.151, 449-463, 1887.

[3] Hertz H. Electric Waves, Collection of Scientific Papers, (Dover, New York, 1962).
[4] Marinov S. *New Measurement of the Earth’s Absolute Velocity with the Help of the ”Coupled Shutters” Experiment*, *Progress in Physics*, 1, 31-37, 2007.

[5] Cahill R.T. and Kitto K. *Michelson-Morley Experiments Revisited*, *Apeiron*, 10(2), 104-117, 2003.

[6] Cahill R.T. *Absolute Motion and Gravitational Effects*, *Apeiron*, 11(1), 53-111, 2004.

[7] Cahill R.T. *The Michelson and Morley 1887 Experiment and the Discovery of Absolute Motion*, *Progress in Physics*, 3, 25-29, 2005.

[8] Cahill R.T. *Dynamical Fractal 3-Space and the Generalised Schrödinger Equation: Equivalence Principle and Vorticity Effects*, *Progress in Physics*, 1, 27-34, 2006.

[9] Cahill R.T. *Gravity, ‘Dark Matter’ and the Fine Structure Constant*, *Apeiron*, 12(2), 144-177, 2005.

[10] Cahill R.T. *‘Dark Matter’ as a Quantum Foam In-flow Effect*, in *Trends in Dark Matter Research*, 96-140, ed. J. Val Blain, Nova Science Pub., New York, 2005.

[11] Cahill R.T. *Black Holes in Elliptical and Spiral Galaxies and in Globular Clusters*, *Progress in Physics*, 3, 51-56, 2005.

[12] Cahill R.T. *Black Holes and Quantum Theory: The Fine Structure Constant Connection*, *Progress in Physics*, 4, 44-50, 2006.

[13] Miller D.C. *Rev. Mod. Phys.*, 5, 203-242, 1933.

[14] Illingworth K.K. *Phys. Rev.* 3, 692-696, 1927.

[15] Joos G. *Ann. d. Physik* [5] 7, 385, 1930.

[16] Jaseja T.S. *et al.* *Phys. Rev.* A 133, 1221, 1964.

[17] Torr D.G. and Kolen P. in *Precision Measurements and Fundamental Constants*, Taylor, B.N. and Phillips, W.D. eds. *Natl. Bur. Stand. (U.S.), Spec. Pub.*, 617, 675, 1984.

[18] Cahill R.T. *The Roland DeWitte 1991 Experiment*, *Progress in Physics*, 3, 60-65, 2006.

[19] Cahill R.T. *A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected*, *Progress in Physics*, 4, 73-92, 2006.

[20] Müller H. *et al.*, *Phys. Rev. Lett.* 91(2), 0204010-1, 2003.

[21] Smoot G.F., Gorenstein M.V. and Muller R.A. *Phys. Rev. Lett.*, 39(14), 898, 1977.

[22] Navia C.E. *et al.*, *Progress in Physics*, 1, 54-61, 2007.