Could the measurements trying to detect absolute motion of Earth allow to test sub-manifold gravity?

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1 Introduction

The history of the modern measurements of absolute motion has a long - more than century beginning from Michelson-Morley 1887. The reader can find in web a list of important publications [1] giving an overall view about what has happened. The earliest measurements assumed aether hypothesis. Cahill identifies the velocity as a velocity with respect to some preferred rest frame and uses relativistic kinematics although he misleadingly uses the terms absolute velocity and aether. The preferred frame could galaxy, or the system defining rest system in cosmology. It would be easy to dismiss this kind of experiments as attempts to return to the days before Einstein but this is not the case. It might be possible to gain unexpected information by this kind of measurements. Already the analysis of CMB spectrum demonstrated that Earth is not at rest in the Robertson-Walker coordinate system used to analysis CMB data and similar motion with respect to galaxy is quite possible and might serve as a rich source of information also in GRT based theory.

In TGD framework the situation is especially interesting.

1. Sub-manifold gravity predicts that the effective light-velocity measured in terms of M^4 time taken for a light signal to propagate from point A to B depends on space-time sheet, on points A and B, in particular the distance between A and B. The maximal signal velocity determined in terms of light-like geodesics has this dependence because light-like geodesics for the space-time surface are in general not light-like geodesics for M^4 but light-like like curves. The maximal signal velocity is in general smaller than its absolute maximum obtained light-like geodesics of M^4, depends on particle, and could be larger than for photon space-time sheets. This might explain neutrino super-luminality [1] [1].

2. Space-time sheets move with respect to larger space-time sheets and it makes sense to speak about the motion of solar system space-time sheet with respect to galactic space-time sheet and this velocity is in principle measurable. Maximal signal velocity can be defined operationally in

terms of time needed to travel from point A to B using Minkowski coordinates of the imbedding space as preferred coordinates. It depends on pair of points involved: basically on the direction on and spatial distance along effectively light-like geodesic defined by the sum of the perturbations of the induced metric for the space-time sheets involved. The question is whether one could say something interesting about various experiments carried out to measure the absolute motion interpreted in terms of velocity of space-time sheet with respect to say galactic space-time-sheet.

Also in Special Relativity the motion relative to the rest system of a larger system is a natural notion. In General Relativistic framework situation should be the same but the mathematical description of the situation is somewhat problematic since Minkowski coordinates are not global due to the loss of Poincare invariance as a global symmetry. In practice one must however introduce linear Minkowski coordinates and this makes sense only if one interprets the general relativistic space-time as a perturbation of Minkowski space. This background dependence is in conflict with general coordinate invariance. For sub-manifold gravity the situation is different.

Could the measurements performed already by Michelson-Morley and followers could provide support for the sub-manifold gravity? This might indeed be the case as the purpose of the following arguments demonstrate. The basic results of this analysis are following.

1. The basic formulas for interferometer experiments using relativistic kinematics instead of Galilean one are same as the predictions of Cahill [3] using different basic assumptions, and allow to conclude that already the data of Mickelson and Morley show the motion of Earth -not with respect to aether- but with galactic rest system.

2. The only difference is the appearance of the maximal signal velocity $c_{\#}$ for space-time sheet to which various gravitational fields contribute. In the static approximation sum of gravitational potentials contributes to $c_{\#}$.

3. This allows to utilize the results of Cahill [3], who has carried out a re-analysis of experiments trying to detect what he calls absolute motion using these formulas. Cahill has also replicated [4] the crucial experiments of Witte [5].

4. The value of the velocity as well as its direction can be determined and the results from various experiments are consistent with each other. The travel time data demonstrate a periodicity due to the rotation of Earth and motion with respect a preferred frame identifiable as a galactic rest frame. The tell-tale signature is the periodicity of sidereal day instead of exact 24 hour periodicity. The travel time for photons shows fluctuations which might be interpreted in terms of gravitational waves having fractal patterns. TGD view about gravitons would suggest that the emission takes place -not as a continuous stream- but in burst-wise manner producing fractal fluctuation spectrum. These fluctuations could show themselves as a jitter also in the neutrino travel times discovered by Opera collaboration [1].

2 The predictions of TGD for the local light-velocity

An interesting question is what various experiments carried out during more than century could allow to conclude about TGD predictions and what they are.

2.1 Theoretical issues

One must answer several questions before one can make predictions.

1. The reduction of light velocity in the case that there are many space-time sheets whose M^4 projections intersect, is described using common M^4 coordinates for the space-time sheets. The induced metric for given space-time sheet is the sum of flat M^4 metric and CP_2 contribution identified as classical gravitational field. The hypothesis is that in good approximation a linear superposition for the effects of the gravitational fields holds true in the sense that a test particle having wormhole throat contacts to these space-time sheets experiences the sum of the gravitational fields of various sheets. Similar description holds for induced gauge fields.

From this one can identify the reduced light velocity in the static situation as $c_\# = \sqrt{g_{tt}}$. In a more realistic necessary non-local treatment one calculates the effective light-velocity by assuming that the orbit of massless state n geometric optics approximation is light-like geodesic for the sum of the metric perturbations: this line is not a light-like geodesic of any of the space-time sheets.

In the general the effective metric defined in this manner is not imbeddable as induced metric. This description of linear super-position allows to circumvent the basic objection against TGD, which is that induced metric and gauge fields are extremely strongly correlated since they are expressible in terms of CP_2 coordinates and their gradients and that the variety of metrics representable as induced metrics is extremely restricted. Same of course applies to gauge fields.

2. How the reduced light-velocity $c_\#$ relates to the reduced light-velocity in medium which is usually described by introducing the notions of free and polarization charges and magnetization and magnetization currents. In the simple situation when polarization tensor is scalar, refractive index n characterizes the reduction of the light velocity: $V = c_\#/n$. Since the reduction of maximal signal velocity due to sub-manifold is purely gravitational and its reduction in medium has an electromagnetic origin, one can argue that the two notions have nothing to do with each other. Hence $c_\#$ should be treated as a local concept possibly depending on direction of motion by taking the limit when light-like geodesic with respect to effective metric becomes infinitesimally short. This dependence can be deduced by comparing light-like geodesics emanating from a point and calculating the maximal signal velocity as a function of direction angles of the light-like geodesic and the spatial distance along it.

3. What happens to the boundary conditions between different media deduced from the structural equations of classical electrodynamics and Maxwell equations? For instance, does the refraction of light take place also when $c_\#$ changes? It might of course be that $c_\#$ changes only in astrophysical scales - maybe at the surfaces of astrophysical objects - and stays constant at the boundaries between two media in laboratory scale but nevertheless this issue should be understood. The safest guess is that at the level of kinematic local Lorentz invariance still holds true so that the tangential wave vectors identifiable in terms of massless momentum components are conserved at boundaries and one obtains law of refraction also now.

4. In TGD Universe space-time sheets can move with respect to each other and the larger space-time sheet defines the analog of absolute reference frame in this kind of situation. Also in cosmology one can assign to CMB radiation a specific frame and Earth indeed moves with respect to it rather than being at rest in the global Robertson-Walker coordinate system. For Earth solar system is one such frame. Galactic rest system is second such preferred reference frame. To both one can assign linear Minkowski coordinates, which play a special physical. The obvious question is whether this kind of motion could be detected and whether the measurements carried out to detect absolute motion could allow to deduce this kind of velocity with respect to galactic rest system.

5. The question is how photons in medium behave when this kind of motion is present. Assume that the medium is characterized by refractive index n so that one has $V = c_\#/n$ and that space-time sheet moves with respect to larger one by velocity v characterized by direction angles and magnitude. Here $c_\# < c_0$ is the maximal signal velocity at the space-time sheet. For definiteness assume that the larger space-time sheet corresponds to galaxy.

   (a) In the measurements of light velocity the light propagates in medium with velocity $V < c_\# < c_0$, and the question is how to describe this mathematically. In his experiments Michelson assumed summation of velocities based on Galilean invariance. This is of course wrong and Special Relativity suggests summation of velocities according to the relativistic formula:

$$
\begin{aligned}
V &\rightarrow V_1(v,u) \equiv \frac{V+vu}{1+\frac{Vv}{c_\#^2}u)} = \frac{V+vu}{V+\frac{v}{nc_\#}u)} \ , \\
V &= \frac{c_\#}{n} \ , \ u = cos(\theta) \ .
\end{aligned}
\tag{2.1}
$$

Here θ is the direction of the light signal with respect to the velocity v. This formula might be justified in TGD framework: also photon has very small but non-vanishing mass and summation formula for velocities can be applied. This demands the assumption of local Lorentz invariance made routinely in General Relativity. Also it requires that the complex process of repeated absorption and emission of photons is described by a propagation of photon with the reduced velocity.

(b) This predicts two effects which might be seen in the experiments trying to measure absolute velocity and its direction. Both solar and galactic gravitational field and also its perturbations - even gravitational waves- can affect the signal velocity via fluctuations in $c_{\#}$ deduced from the superposition of the perturbative contributions of CP_2 to the effective induced metric. Second effect is due to the change of the propagation time. This change depends on the propagation direction. Note however that also $c_{\#}$ in general has the directional dependence and only in the situation when the components g_{ti} vanish, this dependence is trivial. In the Newtonian approximation the assumption $g_{ti} \simeq 0$ is made and corresponds to the description of the situation in terms of gravitational potential.

2.2 Basic predictions

From the above summarized assumptions one can deduce the basic predictions for what should happen in various experiments measuring $c_{\#} < c_0$ and v.

1. One can have gravitational reduction or even increase of the light velocity from its standard value which need not corresponds to its absolute maximum. The model for neutrino super-luminality assumes that $c_{\#}$ characterizes particle space-time sheets - perhaps massless extremals carrying the small deformations of CP_2 type vacuum extremals - topologically condensed aren magnetic flux tubes characterizing particles. For neutrinos one has $(c_{\#} - c_0)/c_0 \sim 10^{-5}$ where $c_0 < c$ is what we have used to call light-velocity in vacuum.

2. The variation of the propagation time visible in interferometer experiments as a variation of the position interference fringes with the direction of light signal demonstrates the possible dependence of the the light velocity on direction. This dependence is predicted for $n > 1$ only. The motion of Earth around Earth induces the variation of the angle θ even in the situation that the interferometer is not rotated.

It is straightforward to derive a formula for the difference of propagation times along orthogonal arms of the interferometer.

1. What determines the position of interference fringes is the quantity

$$r = \frac{\Delta T(v,\theta)}{T_0} \ \ , \ , T_0 = \frac{2L}{V} = \frac{2Ln}{c_{\#}} \ . \tag{2.2}$$

   Here $T(0,0)$ is back and form propagation time for interferometer arm of length L $v = 0$.

2. The time difference ΔT is the difference of times for the propagation back and forth along orthogonal interferometer arms of length L:

$$\begin{aligned} \Delta T &= T(v,\theta) - T(v,\theta+\pi/2) \ , \\ T(v,\theta) &= \frac{L}{V_1(v,u=cos(\theta))} + \frac{L}{V_1(v,-u=cos(\theta+\pi))} \ , \\ V_1(v,u) &= \frac{V+vu}{1+\frac{Vv}{c_{\#}^2}u} \ , \ u = cos(\theta) \ , \ V = \frac{c_{\#}}{n} \ . \end{aligned} \tag{2.3}$$

   Assuming that $\beta = v/c_{\#}$ is small one obtains

$$\frac{\Delta T}{T_0} \simeq (n^2-1)\beta^2 cos(2\theta) = (n^2-1)(\frac{v}{c_{\#}})^2 cos(2\theta) \ . \tag{2.4}$$

The formula contains also dependence on $c_{\#}$ and in principle the interferometer could allow to detect gravitational waves via their effect on $c_{\#}$. The formula is consistent with the formula proposed by Cahill [3]. Unfortunately, I am unable to understand the argument of Cahill, who speaks about Lorentz contractions whereas the above arguments assumes just the relativistic addition formula for velocities.

3. For interferometer experiments using gas phase the deviation of n from unity is small: $n = 1+\epsilon$, $\epsilon << 1$ and one can write in good approximation

$$\frac{\Delta T}{T_0} \simeq 2\epsilon\beta^2 cos(2\theta) = 2\epsilon(\frac{v}{c_{\#}})^2 cos(2\theta) \ . \tag{2.5}$$

4. The Newtonian picture applied by Michelson-Morley and many followers the basic formula would be

$$\frac{\Delta T}{T_0} \simeq 2\beta^2 n^2 cos(2\theta) \ . \tag{2.6}$$

Therefore the value of the velocity deduced by using TGD would be much larger than by using Newtonian kinematics and this means that the small anisotropy of $\beta \simeq 10^{-5}$ reported already by Michelson and Morley is amplified by a factor of order $\sqrt{1/\epsilon} \simeq 10^2/\sqrt{3}$. (one has $\epsilon \simeq 2.9\times 10^{-4}$ for air and becomes of order $\beta \simeq 10^{-3}$ consistent with the value reported by of Torr and Kolen, De Witte, and Cahill in experiments using propagation of RF light in axial cable. Hence the claim of Cahill that already Michelson and Morley measured the anisotropy of velocity of light would make sense also in TGD framework when appropriately re-interpreted.

Second interesting situation corresponds to one-way and two-way propagation times measured for RF waves propagating along straight co-axial cables.

1. In this case the relevant quantity is

$$\begin{aligned} r &= \frac{\Delta T}{T_0} = \frac{T(v,\theta)-T_0}{T_0} \\ &= \frac{1+\frac{\beta u}{n}}{1+\beta u n} - 1 \simeq \beta(\frac{1-n^2}{n})u - \beta^2 u^2 \ , \\ n &= \frac{c_{\#}}{V} \ , \ u = cos(\theta) \ . \end{aligned} \tag{2.7}$$

For $n = 1+\epsilon$, $\epsilon << 1$ has in good approximation

$$\begin{aligned} r &\simeq -2\epsilon\beta u - \beta^2 u^2 \ , \\ n &= \frac{c_{\#}}{V} \ , \ u = cos(\theta) \ . \end{aligned} \tag{2.8}$$

If one writes $c_{\#} = (1+\epsilon_{\#})c_0$ and $n_0 = 1+\epsilon_0$ (no gravitational perturbations) one obtains in good approximation $\epsilon \simeq \epsilon_{\#} + \epsilon_0$. Again it is essential that r is proportional to the deviation $n-1$.

2. For two-way propagation time the relevant quantity is in the same approximation

$$\begin{aligned} r &= \frac{\Delta T}{2T_0} = \frac{T(v,\theta)+T(v,\theta+\pi)-2T_0}{2T_0} \simeq -\beta^2u^2(n^2-1) \simeq -2\epsilon\beta^2u^2 \ , \\ u &= cos(\theta) \ . \end{aligned} \quad (2.9)$$

   The linear term in β is absent in this expression defining the building block of the expression for r interferometer experiments.

All these formulas are consistent with those proposed by Cahill although the argument leading to them is different. The new element is of course the appearance of $c_\#$ bringing in the dependence of the maximal signal velocity on induced space-time metric and therefore gravitational effects.

2.3 What can one say about super-luminal neutrinos in this framework?

The proposed framework applies as such to super-luminal neutrinos reported by OPERA collaboration [1].

1. $n = 1$ is natural for neutrinos so that no directional dependence from the velocity v with respect to the galactic frame is expected. The dependence of $c_\#$ on particle type and on the gravitational fields at other parallel space-time sheets could however explain both super-luminality and the observed jitter in the arrival time [1].

2. The value of $c_\#$ depends on the primary space-time sheet along which the neutrinos propagate and could be larger than for the space-time sheets of photons. Massless extremal topologically condensed at the magnetic flux tubes with neutrinos represented by wormhole contacts is a good candidate for neutrino space-time sheet pair. It is also possible that classical Z^0 fields affect the situation by giving rise to a cyclotron orbit [1].

3. The presence of also other space-time sheets - in particular those assigned to Earth, Sun, and Galaxy - is possible and plausible and they contribute to $c_\#$. This contribution is precisely defined if one accepts that in common M^4 coordinates for space-time sheets the sum of CP_2 contributions to the effective metric determines the effective metric and therefore also $c_\#$. Also the fluctuations of the gravitational fields suggested by Cahill to have interpretation as gravitational waves affect $c_\#$ and therefore maximal signal velocity for neutrinos. The question which does not first come into mind is therefore whether the jitter in the neutrino propagation time is due to gravitational waves!

3 The analysis of Cahill of the measurements trying to measure absolute motion

The primary inspiration for looking various experiments related to the determination of absolute motion came from P. O. Ulianov's proposal described in article *The Witte Effect: The Neutrino Speed and The Anisotropy of the Light Speed, as Defined in the General Theory of Relativity* [6].

Ulianov proposed that one could perhaps understand neutrino super-luminality in terms of Witte effect [5]. This idea does not to work as such. $n = 1$ is natural for neutrinos and would predict vanishing directional effect. If the directional effect is present it would be oscillatory behavior around a value, which is below c and would not allow super-luminality even momentarily. Fluctuations due to the variations of $c_\#$, which itself could be larger than for photon space-time sheets are however possible and could explain the observer jitter in the arrival time [1].

The reading of this article led to the realization that delicate effects related to the many-sheeted space-time concept might have been observed already by Michelson and Morley, who indeed report a small anisotropy for the magnitude of the light velocity- something that TGD based view about maximal signal velocity indeed suggests. I also found that R. T. Cahill had come into similar thoughts so that I decided to study the articles of Cahill.

1. Cahill describes the history of the experiments trying to detect the absolute motion in his article *Absolute Motion and Gravitational Effects* [3]. Cahill has his terminology and own views about the correct interpretation but the open-minded reader should not allow this to disturb too much.

2. A less technical article describing the contribution of De Witte is titled *The Roland De Witte 1991 Experiment (to the Memory of Roland De Witte)* [5].

3. The article *A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected* [4] describes the measurement of Cahill himself using RF waves propagating along co-axial cable. The reader should not take the term "Absolute Motion" too emotionally since it can be replaced with relative motion of a small system with respect to much larger system. The formulas of Witte are also consistent with local Special Relativity although one can disagree about their derivation.

3.1 Re-analysis of old experiments by Cahill

There are two basic methods to measure the value of c and detect its possible dependence on the direction of travel. The interferometer experiments were used by Michelson and Morley [2] and their followers. The measurements of propagation time for RF signal propagating in co-axial cable were carried out by Torr and Kolen, De Witte and by Cahill. Cahill reports [5] that 7 interferometer experiments has been carried out during more than century.

Cahill has re-analyzed [3] the earlier interferometer experiments using his theory and concluded that already these experiments reveal the motion with respect to some system - most naturally galactic rest frame - and allow to deduce the magnitude and direction of the velocity of motion. It must be emphasized that all this is consistent with special relativity: the formulas used are just the above formulas obtained by putting $c_{\#} = c$. Cahill's analysis applies therefore also to TGD predictions. The variability of $c_{\#}$ gives however additional liberty in interpretation.

1. Cahill analyzes the unpublished experiments of De Witte (1991) [5]. RF travel time along co-axial cable was in question. Data was taken over 178 days. The experimental apparatus was already earlier used by Torr and Kolen and is described in detail. The length of the cable was $L = 1.5$ km. The frequency of radio waves was 5 MHz. The refractive index of the cable was $n = 1.5$. The signals were sent between clusters of atomic clocks along RF cable in synchronization purpose.

   The value of the velocity $\beta = v/c$ derived by De Witte and later by Cahill himself, is about 400 km/s corresponding to $\beta \simeq 1.3 \times 10^{-3}$ and surprisingly large. The direction of β coincides with the direction of β given by right ascension ($\alpha = 5.2$ hr, $\delta = 67^0$) deduced by Miller in this interferometer experiments 1932-1933. Cahill interprets β as the velocity of Earth with respect to galactic rest frame. De Witte did not yet realize the possibility of this interpretation. There are also fluctuations in the value of the velocity v deduce in this manner to be discussed later.

   In TGD framework $\Delta T/T$ is proportional $\beta^2 = (vcos(\theta)/c_{\#})^2$ and Earth's rotation causes the oscillatory variation of $cos(\theta)$, which is indeed seen: see Fig. 1 of the article. Fluctuations in propagation time can be understood as being due to the fluctuations of $c_{\#}$.

2. Cahill re-analyzes [3] the earlier interferometer experiments using what is equivalent with relativistic addition formula for the velocities applied to photons with $V < c$. All interferometer experiments have been regarded to be consistent with Special Relativity. Michelson and Morley (1887) and also Miller (1932-1933) however observed small fringe shifts but interpreted them as measurement errors.

   (a) Miller found $v = 10$ km/s and also deduced the right ascension for the velocity as (α, δ) = (5.2 hr, 67^o). Cahill obtains $v = 420 \pm 30$ km/s from the re-analysis of Miller experiments and interprets it as a velocity with respect to galactic rest frame. CMB anisotropy corresponds to a motion with respect to "cosmic" rest frame and is 369 km/s in direction characterize by right ascension (α, δ)=(11.20 hr,-7.22^o(, which differs Miller's direction.

   Cahill improves his fit by introducing to velocity field corrections which he calls in-flows and defined from the formula $v^2 = \Phi_{gr}$ for Earth and Sun assuming that v is in radial direction. The corrections are measured using 10 km/s as a natural unit. The first guess is that these corrections might be understood in TGD framework in terms of the effect of the dependence of $c_\# = \sqrt{g_{tt}}$ in static approximation on the gravitational potentials of Earth and Sun.

(b) The value of v from Michelson-Morley experiments using Galilean kinematics would be about $v = 9$ km/s gives $\beta = v/c \simeq 10^{-5}$. Cahill deduces the value of v using what reduces to relativistic kinematics and obtains $v = 328 \pm 50$ km/s. Cahill also performs a fit using Miller's velocity and direction and obtains what he regards as a good fit.

(c) Cahill has also repeated the experiments of Witte with improved technology (2006) and reports the results int he article *A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected* [4] and obtains results consistent with those of Witte. Unfortunately the terminology of the title and the use of the taboo terms "absolute motion" and "aether" serving as deeply emotional signals for the members of the academic mainstream creates easily mis-interpretations. The motion is relative and most naturally relative to the galactic rest system.

3.2 Additional observations

Already Witte and later Cahill makes the following additional observations.

1. Already Witte observed that the effective velocity deduced from $\Delta T/T$ for one-way propagation time has an oscillatory behavior with a period consistent with the sidereal day suggesting that the fluctuation is caused by galactic gravitational field rather than being of solar origin. Hence v would have the most natural interpretation as a velocity for the motion with respect to galactic rest frame.

2. All these experimenters find fluctuations - "turbulence"- in the magnitude of the velocity v deduced using the basic formulas. The fluctuations are illustrated by Fig. 2 of the article [5]. Cahill reports that the fluctuations have a fractal spectrum (in the sense that no scale is present).

   The model of Cahill forces to assign these fluctuations to the velocity field v. The assumption that the velocity of a solar sized system could fluctuate so rapidly looks non-realistic. Cahill indeed introduces a modification of general relativity in which 3-space is the fundamental object and gravitational field is replaced by a velocity field so that the fluctuations of velocity field would correspond to those of gravitational field. Cahill also suggests the interpretation of the fluctuations as gravitational waves: this looks much more reasonable than the fluctuations in velocity of Earth. Velocity field is assigned to what Cahill calls quantum foam. To me this idea does not look attractive.

   Cahill seems to identify the density of the non-relativistic kinetic energy as gravitational potential: $v^2/2 = \Phi_{gr}$. In Newtonian theory this would correspond to the vanishing of the total energy density. In TGD framework the analog would be the identification of the phase in which Einstein's equations holds true as vacuum extremals for which the induced Kähler field vanishes. Any 4-surface with a CP_2 projection which is Lagrangian and thus at most 2-D sub-manifold of CP_2 satisfies this condition. $c_\# = c$ restriction leaves no other possibility.

   In TGD framework the fluctuations can be assigned to $c_\#$ and therefore to gravitational potential in static approximation so that gravitational waves or their analogs could indeed be in question. Certainly gravitational waves should make themselves visible in $\Delta T/T$. $\Delta c_\#/c_\#$ for the fluctuations would be below 10^{-3}. The amplitude of the fluctuations seem quite large but the idea about the bursts of ordinary gravitons created in the decays of large $\hbar$ gravitons very large energy might produce fractal spectrum.

3. Cahill correctly notices that the interpretation of the interferometer experiments proposed by Michelson and Morley and followers is wrong because a non-relativistic addition formula for the addition of velocities is used. Cahill re-interprets the experiments using formulas which are equivalent with those obtained by replacing Galilean addition of velocities with Lorentzian one, and finds that with his assumptions the findings of the earlier experiments conform with the findings from co-axial cable experiments.

I must admit that I do not understand the argument of Cahill. Cahill however concludes that ΔT must be proportional to $n(n^2-1)$ rather than n^3 and this implies that the value of β deduced from interferometer experiments is for $n \sim 1$ by a factor $n/\sqrt{n^2-1}$ larger than in Newtonian framework. Cahill also correctly notices that $n > 1$ is essential for a non-trivial effect so that only gas interferometers are capable of observing the motion with respect to galactic rest system. This is obvious from the relativistic additional formula for velocities.

4. Cahill as an honest experimentalist notices also that there is an issue, which is not understood at all in his interpretation. Optical fibers would provide and excellent manner to test the theory. Fiber can be in a form of loop and even 4 meter long fiber could be enough as Cahill notices.

   (a) The amazing finding is that there is no directional effect in this case. Cahill calls this optical fiber effect [4]. Anti-crackpot would of course immediately conclude that the case is closed. As an inhabitant of TGD Universe I have however learned to be very cautious in this kind of situations. There are two manners to reduce the local light velocity.

      i. The standard manner is based on electromagnetic interactions and boils down to refractive index n.

      ii. The new manner relies on gravitational interactions and boils down to deviation of $c_\#$ from c_0. This allows $c_\#$ to depend on condensed matter phase- parameters characterizing the material, to have a slow dependence on position in astrophysical scales, as well as the dependence on the direction of and spatial distance along light-like geodesic in the effective metric (involving sum over CP_2 contributions associated with various space-time sheets involved), and even the dependence on gravitational waves inducing time dependent modification of the effective metric.

   (b) The conservative attitude is that $n = 1.5$ for the optical fiber at the static limit is due to electromagnetic interactions but that for the specific frequencies used in IR transmissions $n(f) =\simeq 1$ holds true in excellent approximation. The use of index of refraction at the zero frequency limit would be simply wrong. If I have understood correctly the propagation without absorptions and reflections is the defining property of an ideal optical fibre. This would mean that the light at the frequencies considered propagates without any interactions except the reflections at the boundaries of the optical fiber.

   (c) Could the reduction of light velocity from c_0 for optical fiber be mostly due to the reduction of $c_\#$ so that in good approximation one would have $n = 1$? This hypothesis is rather radical and would mean that gravitational physics becomes an essential part of condensed matter physics. What one expects is refraction of gravitational waves and this is expected to take place in astrophysical rather than the scales of the everyday world. This proposal should be also consistent with the meaning of refractive index. In particular, the reduction of light velocity gravitational should give rise to the refraction of light waves also now. For these reasons this proposal does not look realistic.

4 Cahill's work in relation to TGD

Cahill has also introduced a theoretical framework to explain the findings of De Witte and reinterpreted interferometer experiments.

1. Cahill claims that the $v \sim 400$ km/s of Earth with respect to a galactic rest system explains roughly the findings of various experiments. To improve the fit Cahill introduces additional velocities which he interprets as velocities of quantum foam towards Sun and Earth respectively. Cahill seems to interpret gravitational potential as a density of non-relativistic kinetic energy per unit mass: $v^2/2 = \Phi_{gr}$. In TGD framework It might be possible to interpret these additional contributions to the velocity field as counterparts for the contributions of the gravitational potentials of Sun and Earth to the overall gravitational potential and affective $c_\#$ and providing it with a directional dependence.

2. If I have understood correctly Cahill assumes that Lorentz-Fitzgerald contraction occurs but in the Earth's rest system rather than in the rest system with respect to which Earth is moving.

The motivation for the assumption is that in the rest system of galaxy time dilation would compensate Lorentz contraction completely. Cahill notices that the deviation of V from c is essential and gives rise to a non-trivial effect for interferometer which is not idealizable as empty space ($n = c/V > 1$). I must admit that I do not understand here Cahill's argument although he ends up with the same formula for $\Delta T/T$ as I do using relativistic addition formula for velocities.

3. Cahill has proposed what he calls quantum flow information theory of gravity [1]. Cahill introduces velocity field v, which replaces gravitational potential: $v^2 \propto \Phi_{gr}$, where Φ_{gr} is Newtonian gravitational potential is the basic identification. The motivation is presumably the necessity to introduce radial inward velocities to Sun and Earth in order to improve the interpretation of the various experiments trying to detect absolute motion. Space-time is replaced with 3-space but special relativity is assumed to hold true. This of course makes the theory vulnerable to criticism and D. Martin has criticized Cahill's quantum flow information theory of gravity in *Comments on Cahills quantum foam inflow theory of gravity* [2].

4. The quantum foam in-flow has a physical analogy in TGD framework. Gravitational acceleration involves real four-momentum transfer in TGD Universe. By quantum classical correspondence this transfer should have a space-time counterpart and could be realized in terms of topological field quanta, presumably magnetic flux tubes along which gravitons propagate. The attractiveness of gravitation means inward momentum flux. This picture has been applied to explain Allais effect [3] in terms of the large Planck constant assignable to space-time sheets mediating gravitational interactions. I have also suggested that the gigantic value of gravitational Planck constant implies that large $\hbar$ gravitons decay to bursts of ordinary gravitons and instead of a continuous flow of gravitons there would be bursts which would be probably interpreted as noise [2]. This might even lead to a failure to detect gravitons. The evidence for the fluctuations in the spectrum of $\Delta T/T$ for the travel time in the experiments trying to detect absolute motion might conform with this interpretation.

So: What attitude should one take on Cahill?

1. Anti-crackpot would resolve the irritating cognitive dissonance by claiming that Torr and Kolen, Witte, and Cahill make the same systematic error in their measurements. Experimental apparatus is indeed essentially the same. Also the absence of the directional dependence for optical fibers provides a weapon for easy debunking.

2. The appearance of the sidereal day as a period produces problems for the anti-crackpot. Any systematic effect - say to temperature variations - would have exactly 24 hours period. Anti-crackpot can of course argue that the period is actually this and that sidereal day as period is due to a systematic error or wishful thinking. This is however not very convincing argument. What is also irritating is the fact that the simple formula of Cahill deducible directly from the relativistic formula for the addition of velocities allows to understand satisfactorily all experiments in terms of single velocity β in direction determined by Miller. Could it be that the experiments are right and there is indeed a motion of Earth relative to galaxy causing non-trivial effects?

3. Anti-crackpot might also argue that the model used by Cahill to analyze the experiments is wrong so that the whole issue should be forgotten. Basic formulas are however consistent with special relativity. To my opinion the other notions introduced by Cahill might be seen as an attempt to right direction and could have interpretation in terms of $c_{\#}$ interpreted in terms of a sum of gravitational potentials at the static limit. The genuine new element is that local light velocity can be affected also by gravitation besides electromagnetic effects.

I have nothing personal against theorists but my own conclusion based on experience of decades is that I trust more on experimentalists than theorists. Cahill and his predecessors are excellent experimentalists and might have been able to make discoveries much before the time is ripe for them. These experiments not only give direct support for TGD but could even provide new approach to detect time dependent gravitational perturbations and perhaps even gravitational waves. Although I cannot agree with the theoretical proposals of Cahill, I must admit that they have analogs in TGD framework.

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