TGD and Possible Gravitational Anomalies

M. Pitkänen,

February 2, 2024
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.
Postal address: Rinnekatu 2-4 A 8, 03620, Karkkila, Finland. ORCID: 0000-0002-8051-4364.

Contents

Abstract

In this chapter the applications of TGD to various real or potential anomalies of GRT approach are discussed.

1. In the first section Allais effect as a possible evidence for large $\hbar$ dark gravitons is discussed.
2. TGD inspired model of gravimagnetism is studied. There are claims about strong gravimagnetism and these claims are considered in terms large $\hbar$ hypothesis.
3. The dependence of operationally defined light velocity on space-time sheet distinguishes between the sub-manifold gravity of TGD and the abstract manifold gravity GRT. Possible evidence for the effect is discussed. These effects are discussed in several sections. Also the time dilation effect caused by the warping of space-time sheet in absence of matter is considered.
4. There are also some considerations not strictly related to anomalies such as possible interpretations of Machian Principle in TGD framework.

1 Introduction

In this chapter the applications of TGD to various real or potential anomalies of GRT approach are discussed.

1. Allais effect represents one of the anomalies associated with gravitational interaction discarded by the average theoretician. In TGD framework this effect could be interpreted as an interference effect made possible by the gigantic value of gravitational Planck constant [K6]. As an interference effect it is extremely sensitive to the parameters of the problem and this explains why the sign and size of the effects varies so much.

2. Gravimagnetism is one of the predictions of GRT which is being tested experimentally. TGD predicts deviations from the predictions of GRT which unfortunately are not seen in the satellite experiment to be discussed below. The claimed discovery of gravimagnetic effect in super-conductors having strength 20 orders of magnitude larger than predicted by GRT raises the question whether TGD might explain the effect. TGD inspired model of gravimagnetism is studied. The claims about strong gravimagnetism are considered in terms large $\hbar$ hypothesis. It turns out that the identification $h_{gr} = h_{eff}$ at elementary particle level and assumption that h_{gr} for superconductor corresponds to h_{gr} for Earth Cooper pair system predicts correctly the amplification factor needed to obtain strong enough gravimagnetic variant of Thomson magnetic field to explaoin the discrepancy motivating the work of Tajmar *et al.* Also a direct connection with hypothesis identifying EEG photons as dark photons decaying to ordinary visible photons emerges.

3. For many-sheeted space-time light velocity is assigned to light-like geodesic of space-time sheet rather than light-like geodesics of embedding space $M^4 \times CP_2$. The effective velocity determined from time to travel from point A to B along different space time sheets is different and therefore also the signal velocity determined in this way. The light-like geodesics of space-time sheet corresponds in the generic case time-like curves of the embedding space so that the light-velocity is reduced from the maximal signal velocity. Space-time sheet is bumpy and wiggled so that the path is longer. Each space-time sheet corresponds to different light velocity as determined from the travel time. The maximal signal velocity is reached only in an ideal situation when the space-time geodesics are geodesics of Minkowski space.The dependence of operationally defined light velocity on space-time sheet distinguishes between the sub-manifold gravity of TGD and the abstract manifold gravity GRT. Possible evidence for the effect is discussed. These effects are discussed in several sections.

4. There exists an infinite number of warped imbeddings of M^4 to $M^4 \times CP_2$, which are metrically equivalent with the canonical imbedding with CP_2 coordinates constant. These imbeddings are characterized by anomalous time dilation due to the warping even when gravitational fields are absent and the dilation can be large. It is conceivable that preferred extremals obtained as deformations of these warped M^4:s are possible.

5. There are also some considerations not strictly related to anomalies such as possible interpretations of Machian Principle in TGD framework.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2].

2 Allais Effect And TGD

Allais effect represents one of the anomalies associated with gravitational interaction discarded by the average theoretician. In TGD framework this effect can be interpreted as an interference effect made possible by the gigantic value of gravitational Planck constant. As an interference effect it is extremely sensitive to the parameters of the problem and this explains why the sign and size of the effects varies so much.

2.1 The Effect

Allais effect [E2, E22] is a fascinating gravitational anomaly associated with solar eclipses. It was discovered originally by M. Allais, a Nobelist in the field of economy, and has been reproduced in several experiments but not as a rule. The experimental arrangement uses so called paraconical pendulum, which differs from the Foucault pendulum in that the oscillation plane of the pendulum can rotate in certain limits so that the motion occurs effectively at the surface of sphere.

2.1.1 Experimental findings

Consider first a brief summary of the findings of Allais and others [E22].

1. In the ideal situation (that is in the absence of any other forces than gravitation of Earth) paraconical pendulum should behave like a Foucault pendulum. The oscillation plane of the paraconical pendulum however begins to rotate.

2. Allais concludes from his experimental studies that the orbital plane approach always asymptotically to a limiting plane and the effect is only particularly spectacular during the eclipse. During solar eclipse the limiting plane contains the line connecting Earth, Moon, and Sun. Allais explains this in terms of what he calls the anisotropy of space.

3. Some experiments carried out during eclipse have reproduced the findings of Allais, some experiments not. In the experiment carried out by Jeverdan and collaborators in Romania it was found that the period of oscillation of the pendulum decreases by $\Delta f/f \simeq 5\times 10^{-4}$ [E2, E21] which happens to correspond to the constant $v_0 = 2^{-11}$ appearing in the formula of the gravitational Planck constant. It must be however emphasized that the overall magnitude of $\Delta f/f$ varies by five orders of magnitude. Even the sign of $\Delta f/f$ varies from experiment to experiment.

4. There is also quite recent finding by Popescu and Olenici, which they interpret as a quantization of the plane of oscillation of paraconical oscillator during solar eclipse [E25]. There is also evidence that the effect is present also before and after the full eclipse. The time scale is 1 hour.

2.1.2 TGD based models for Allais effect

I have already earlier proposed an explanation of the effect in terms of classical Z^0 force [K2]. If the Z^0 charge to mass ratio of pendulum varies and if Earth and Moon are Z^0 conductors, the resulting model is quite flexible and one might hope it could explain the high variation of the experimental results.

The rapid variation of the effect during the eclipse is however a problem for this approach and suggests that gravitational screening or some more general interference effect might be present.

Gravitational screening alone cannot however explain Allais effect. Also the combination of gravitational screening and Z^0 force assuming Z^0 conducting structures causing screening fails to explain the discontinuous behavior when massive objects are collinear.

A model based on the idea that gravitational interaction is mediated by topological light rays (MEs) and that gravitons correspond to a gigantic value of the gravitational Planck constant however explains the Allais effect as an interference effect made possible by macroscopic quantum coherence in astrophysical length scales. Equivalence Principle fixes the model to a high degree and one ends up with an explicit formula for the anomalous gravitational acceleration and the general order of magnitude and the large variation of the frequency change as being due to the variation of the distance ratio $r_{S,P}/r_{M,P}$ (S, M, and P refer to Sun, Moon, and pendulum respectively). One can say that the pendulum acts as an interferometer.

2.2 Could Gravitational Screening Explain Allais Effect

The basic idea of the screening model is that Moon absorbs some fraction of the gravitational momentum flow of Sun and in this manner partially screens the gravitational force of Sun in a disk like region having the size of Moon's cross subsection. The screening is expected to be strongest in the center of the disk. Screening model happens to explain the findings of Jevardan but fails in the general case. Despite this screening model serves as a useful exercise.

2.2.1 Constant external force as the cause of the effect

The conclusions of Allais motivate the assumption that quite generally there can be additional constant forces affecting the motion of the paraconical pendulum besides Earth's gravitation. This means the replacement $\overline{g} \rightarrow \overline{g}+\Delta\overline{g}$ of the acceleration g due to Earth's gravitation. $\Delta\overline{g}$ can depend on time.

The system obeys still the same simple equations of motion as in the initial situation, the only change being that the direction and magnitude of effective Earth's acceleration have changed so that the definition of vertical is modified. If $\Delta\overline{g}$ is not parallel to the oscillation plane in the original situation, a torque is induced and the oscillation plane begins to rotate. This picture requires that the friction in the rotational degree of freedom is considerably stronger than in oscillatory degree of freedom: unfortunately I do not know what the situation is.

The behavior of the system in absence of friction can be deduced from the conservation laws of energy and angular momentum in the direction of $\overline{g} + \Delta\overline{g}$. The explicit formulas are given by

$$\begin{aligned} E &= \frac{ml^2}{2}(\frac{d\Theta}{dt})^2 + sin^2(\Theta)(\frac{d\Phi}{dt})^2 + mglcos(\Theta) \ , \\ L_z &= ml^2sin^2(\Theta)\frac{d\Phi}{dt} \ . \end{aligned} \tag{2.1}$$

and allow to integrate Θ and Φ from given initial values.

2.2.2 What causes the effect in normal situations?

The gravitational accelerations caused by Sun and Moon come first in mind as causes of the effect. Equivalence Principle implies that only relative accelerations causing analogs of tidal forces can be in question. In GRT picture these accelerations correspond to a geodesic deviation between the surface of Earth and its center. The general form of the tidal acceleration would thus the difference of gravitational accelerations at these points:

$$\Delta\overline{g} = -2GM[\frac{\Delta\overline{r}}{r^3} - 3\frac{\overline{r}\cdot\Delta\overline{r}\overline{r}}{r^5}] \ . \tag{2.2}$$

Here $\overline{r}$ denotes the relative position of the pendulum with respect to Sun or Moon. $\Delta\overline{r}$ denotes the position vector of the pendulum measured with respect to the center of Earth defining the geodesic deviation. The contribution in the direction of $\Delta\overline{r}$ does not affect the direction of the Earth's acceleration and therefore does not contribute to the torque. Second contribution corresponds to an acceleration in the direction of $\overline{r}$ connecting the pendulum to Moon or Sun. The direction of this vector changes slowly.

This would suggest that in the normal situation the tidal effect of Moon causes gradually changing force $m\Delta\overline{g}$ creating a torque, which induces a rotation of the oscillation plane. Together with dissipation this leads to a situation in which the orbital plane contains the vector $\Delta\overline{g}$ so that no torque is experienced. The limiting oscillation plane should rotate with same period as Moon around Earth. Of course, if effect is due to some other force than gravitational forces of Sun and Earth, paraconical oscillator would provide a way to make this force visible and quantify its effects.

2.2.3 What would happen during the solar eclipse?

During the solar eclipse something exceptional must happen in order to account for the size of effect. The finding of Allais that the limiting oscillation plane contains the line connecting Earth, Moon, and Sun implies that the anomalous acceleration $\Delta|g$ should be parallel to this line during the solar eclipse.

The simplest hypothesis is based on TGD based view about gravitational force as a flow of gravitational momentum in the radial direction.

1. For stationary states the field equations of TGD for vacuum extremals state that the gravitational momentum flow of this momentum. Newton's equations suggest that planets and moon absorb a fraction of gravitational momentum flow meeting them. The view that gravitation is mediated by gravitons which correspond to enormous values of gravitational Planck constant in turn supports Feynman diagrammatic view in which description as momentum exchange makes sense and is consistent with the idea about absorption. If Moon absorbs part of this momentum, the region of Earth screened by Moon receives reduced amount of gravitational momentum and the gravitational force of Sun on pendulum is reduced in the shadow.

2. Unless the Moon as a coherent whole acts as the absorber of gravitational four momentum, one expects that the screening depends on the distance travelled by the gravitational flux inside Moon. Hence the effect should be strongest in the center of the shadow and weaken as one approaches its boundaries.

3. The opening angle for the shadow cone is given in a good approximation by $\Delta\Theta = R_M/R_E$. Since the distances of Moon and Earth from Sun differ so little, the size of the screened region has same size as Moon. This corresponds roughly to a disk with radius $.27 \times R_E$.

   The corresponding area is 7.3 per cent of total transverse area of Earth. If total absorption occurs in the entire area the total radial gravitational momentum received by Earth is in good approximation 92.7 per cent of normal during the eclipse and the natural question is whether this effective repulsive radial force increases the orbital radius of Earth during the eclipse.

   More precisely, the deviation of the total amount of gravitational momentum absorbed during solar eclipse from its standard value is an integral of the flux of momentum over time:

$$\begin{aligned} \Delta P^k_{gr} &= \int \frac{\Delta P^k_{gr}}{dt}(S(t))dt \ , \\ \frac{\Delta P^k_{gr}}{dt}(S(t)) &= \int_{S(t)} J^k_{gr}(t)dS \ . \end{aligned} \tag{2.3}$$

   This prediction could kill the model in classical form at least. If one takes seriously the quantum model for astrophysical systems predicting that planetary orbits correspond to Bohr orbits with gravitational Planck constant equal to $\hbar_{gr} = GMm/v_0$, $v_0 = 2^{-11}$, there should be not effect on the orbital radius. The anomalous radial gravitational four-momentum could go to some other degrees of freedom at the surface of Earth.

4. The rotation of the oscillation plane is largest if the plane of oscillation in the initial situation is as orthogonal as possible to the line connecting Moon, Earth and Sun. The effect vanishes when this line is in the initial plane of oscillation. This testable prediction might explain why some experiments have failed to reproduce the effect.

5. The change of $|\overline{g}|$ to $|\overline{g}+\Delta\overline{g}|$ induces a change of oscillation frequency given by

$$\frac{\Delta f}{f} = \frac{\overline{g}\cdot\Delta\overline{g}}{g^2} = \frac{\Delta g}{g}cos(\theta) \ . \tag{2.4}$$

If the gravitational force of the Sun is screened, one has $|\overline{g}+\Delta\overline{g}| > g$ and the oscillation frequency should increase. The upper bound for the effect corresponds to vertical direction is obtained from the gravitational acceleration of Sun at the surface of Earth:

$$\frac{|\Delta f|}{f} \leq \frac{\Delta g}{g} = \frac{v_E^2}{r_E} \simeq 6.0\times 10^{-4} \ . \tag{2.5}$$

2.2.4 What kind of tidal effects are predicted?

If the model applies also in the case of Earth itself, new kind of tidal effects are predicted due to the screening of the gravitational effects of Sun and Moon inside Earth. At the night-side the paraconical pendulum should experience the gravitation of Sun as screened. Same would apply to the "night-side" of Earth with respect to Moon.

Consider first the differences of accelerations in the direction of the line connecting Earth to Sun/Moon: these effects are not essential for tidal effects. The estimate for the ratio for the orders of magnitudes of the these accelerations is given by

$$\frac{|\Delta\overline{g}_{\perp}(Moon)|}{|\Delta\overline{g}_{\perp}(Sun)|} = \frac{M_S}{M_M}(\frac{r_M}{r_E})^3 \simeq 2.17 \ . \tag{2.6}$$

The order or magnitude follows from $r(Moon) = .0026$ AU and $M_M/M_S = 3.7\times 10^{-8}$. These effects are of same order of magnitude and can be compensated by a variation of the pressure gradients of atmosphere and sea water. The effects caused by Sun are two times stronger. These effects are of same order of magnitude and can be compensated by a variation of the pressure gradients of atmosphere and sea water.

The tangential accelerations are essential for tidal effects. They decompose as

$$\frac{1}{r^3}\left[\Delta\overline{r} - 3|\Delta\overline{r}|cos(\Theta)\frac{\overline{r}}{r}\right] \ .$$

$\pi/4 \leq \Theta \leq \pi/2$ is the angle between $\Delta\overline{r}$ and $\overline{r}$. The above estimate for the ratio of the contributions of Sun and Moon holds true also now and the tidal effects caused by Sun are stronger by a factor of two.

Consider now the new tidal effects caused by the screening.

1. Tangential effects on day-side of Earth are not affected (night-time and night-side are of course different notions in the case of Moon and Sun). At the night-side screening is predicted to reduce tidal effects with a maximum reduction at the equator.

2. Second class of new effects relate to the change of the normal component of the forces and these effects would be compensated by pressure changes corresponding to the change of the effective gravitational acceleration. The night-day variation of the atmospheric and sea pressures would be considerably larger than in Newtonian model.

The intuitive expectation is that the screening is maximum when the gravitational momentum flux travels longest path in the Earth's interior. The maximal difference of radial accelerations

M_M/M_S	M_E/M_S	R_M/R_E	d_{E-S}/AU	d_{E-M}/AU
3.0×10^{-6}	3.69×10^{-8}	.273	1	.00257
R_E/d_{E-S}	R_E/d_{E-M}	g_S/g	g_M/g	
4.27×10^{-5}	01.7×10^{-7}	6.1×10^{-4}	2.8×10^{-4}	

Table 1: Table gives basic data relevant for tidal effects. The subscript E,S,M refers to Earth, Sun, Moon; R refers to radius; d_{X-Y} refers to the distance between X and Y g_S and g_M refer to accelerations induced by Sun and Moon at Earth surface. $g = 9.8$ m/s^2 refers to the acceleration of gravity at surface of Earth. One has also $M_S = 1.99\times 10^{30}$ kg and $AU = 1.49\times 10^{11}$ m, $R_E = 6.34\times 10^6$ m.

associated with opposite sides of Earth along the line of sight to Moon/Sun provides a convenient manner to distinguish between Newtonian and TGD based models:

$$\begin{aligned} |\Delta\overline{g}_{\perp,N}| &= 4GM\times\frac{R_E}{r^3} \ , \\ |\Delta\overline{g}_{\perp,TGD}| &= 4GM\times\frac{1}{r^2} \ . \end{aligned} \tag{2.7}$$

The ratio of the effects predicted by TGD and Newtonian models would be

$$\begin{aligned} \frac{|\Delta\overline{g}_{\perp,TGD}|}{|\Delta\overline{g}_{\perp,N}|} &= \frac{r}{R_E} \ , \\ \frac{r_M}{R_E} &= 60.2 \ , \ \frac{r_S}{R_E} = 2.34\times 10^4 \ . \end{aligned} \tag{2.8}$$

The amplitude for the oscillatory variation of the pressure gradient caused by Sun would be

$$\Delta|\nabla p_S| = \frac{v_E^2}{r_E} \simeq 6.1\times 10^{-4}g$$

and the pressure gradient would be reduced during night-time. The corresponding amplitude in the case of Moon is given by

$$\frac{\Delta|\nabla p_s|}{\Delta|\nabla p_M|} = \frac{M_S}{M_M}\times(\frac{r_M}{r_S})^3 \simeq 2.17 \ .$$

$\Delta|\nabla p_M$ is in a good approximation smaller by a factor of 1/2 and given by $\Delta|\nabla p_M| = 2.8\times 10^{-4}g$. Thus the contributions are of same order of magnitude.

One can imagine two simple qualitative killer predictions assuming maximal gravitational screening.

1. Solar eclipse should induce anomalous tidal effects induced by the screening in the shadow of the Moon.

2. The comparison of solar and moon eclipses might kill the scenario. The screening would imply that inside the shadow the tidal effects are of same order of magnitude at both sides of Earth for Sun-Earth-Moon configuration but weaker at night-side for Sun-Moon-Earth situation.

2.2.5 An interesting co-incidence

The value of $\Delta f/f = 5\times 10^{-4}$ in experiment of Jeverdan is exactly equal to $v_0 = 2^{-11}$, which appears in the formula $\hbar_{gr} = GMm/v_0$ for the favored values of the gravitational Planck constant. The predictions are $\Delta f/f \leq \Delta p/p \simeq 3\times 10^{-4}$. Powers of $1/v_0$ appear also as favored scalings of Planck constant in the TGD inspired quantum model of bio-systems based on dark matter [K4]. This co-incidence would suggest the quantization formula

$$\frac{g_E}{g_S} = \frac{M_S}{M_E} \times \frac{R_E^2}{r_E^2} = v_0 \tag{2.9}$$

for the ratio of the gravitational accelerations caused by Earth and Sun on an object at the surface of Earth.

It must be however admitted that the larger variation in the magnitude and even sign of the effect does not favor this kind of interpretation.

2.2.6 Summary of the predicted new effects

Let us sum up the basic predictions of the model assuming maximal gravitational screening.

1. The first prediction is the gradual increase of the oscillation frequency of the conical pendulum by $\Delta f/f \leq 3 \times 10^{-4}$ to maximum and back during night-time in case that the pendulum has vanishing Z^0 charge. Also a periodic variation of the frequency and a periodic rotation of the oscillation plane with period co-inciding with Moon's rotation period is predicted. Already Allais observed both 24 hour cycle and cycle which is slightly longer and due to the fact that Moon rates around Earth.

2. A paraconical pendulum with initial position, which corresponds to the resting position in the normal situation should begin to oscillate during solar eclipse. This effect is testable by fixing the pendulum to the resting position and releasing it during the eclipse. The amplitude of the oscillation corresponds to the angle between $\overline{g}$ and $\overline{g}+\Delta\overline{g}$ given in a good approximation by

$$sin[\Theta(\overline{g}, \overline{g}+\Delta\overline{g})] = \frac{\Delta g}{g} sin[\Theta(\overline{g}, \Delta\overline{g})] \ . \tag{2.10}$$

   An upper bound for the amplitude would be $\Theta \leq 3\times 10^{-4}$, which corresponds to.015 degrees. Z^0 charge of the pendulum would modify this simple picture.

3. Gravitational screening should cause a reduction of tidal effects at the "night-side" of Moon/Sun. The reduction should be maximum at "midnight". This reduction together with the fact that the tidal effects of Moon and Sun at the day side are of same order of magnitude could explain some anomalies know to be associated with the tidal effects [F1]. A further prediction is the day-night variation of the atmospheric and sea pressure gradients with amplitude which is for Sun $3 \times 10^{-4} g$ and for Moon $1.3 \times 10^{-3} g$.

To sum up, the predicted anomalous tidal effects and the explanation of the limiting oscillation plane in terms of stronger dissipation in rotational degree of freedom could kill the model assuming only gravitational screening.

2.2.7 Comparison with experimental results

The experimental results look mutually contradictory in the context provided by the model assuming only screening. Some experiments find no anomaly at all as one learns from [E2]. There are also measurements supporting the existence of an effect but with varying sign and quite different orders of magnitude. Either the experimental determinations cannot be trusted or the model is too simple.

1. The *increase* (!) of the frequency observed by Jeverdan and collaborators reported in Wikipedia article [E2] for Foucault pendulum is $\Delta f/f \simeq 5 \times 10^{-4}$ would support the model even quantitatively since this value is only by a factor 5/3 higher than the maximal effect allowed by the screening model. Unfortunately, I do not have an access to the paper of Jeverdan *et al* to find out the value of $cos(\Theta)$ in the experimental arrangement and whether there is indeed a decrease of the period as claimed in Wikipedia article. In [E16] two experiments supporting an effect $\Delta g/g = x \times 10^{-4}$, $x = 1.5$ or 2.6 but the sign of the effect is different in these experiments.

2. Allais reported an anomaly $\Delta g/g \sim 5\times10^{-6}$ during 1954 eclipse [E6]. According to measurements by authors of [E16] the period of oscillation increases and one has $\Delta g/g \sim 5 \times 10^{-6}$. Popescu and Olenici report a decrease of the oscillation period by $(\Delta g/g)cos(\Theta) \simeq 1.4\times10^{-5}$.

3. In [E20] a *reduction* of vertical gravitational acceleration $\Delta g/g = (7.0\pm2.7)\times10^{-9}$ is reported: this is by a factor 10^{-5} smaller than the result of Jeverdan.

4. Small pressure waves with $\Delta p/p = 2 \times 10^{-5}$ are registered by some micro-barometers [E6] and might relate to the effect since pressure gradient and gravitational acceleration should compensate each other. $\Delta gcos(\Theta)/g$ would be about 7 per cent of its maximum value for Earth-Sun system in this case. The knowledge of the sign of pressure variation would tell whether effective gravitational force is screened or amplified by Moon.

2.3 Allais Effect As Evidence For Large Values Of Gravitational Planck Constant?

One can represent rather general counter arguments against the models based on Z^0 conductivity and gravitational screening if one takes seriously the puzzling experimental findings concerning frequency change.

1. Allais effect identified as a rotation of oscillation plane seems to be established and seems to be present always and can be understood in terms of torque implying limiting oscillation plane.

2. During solar eclipses Allais effect however becomes much stronger. According to Olenici's experimental work the effect appears always when massive objects form collinear structures.

3. The behavior of the change of oscillation frequency seems puzzling. The sign of the frequency increment varies from experiment to experiment and its magnitude varies within five orders of magnitude.

2.3.1 What one an conclude about general pattern for $\Delta f/f$?

The above findings allow to make some important conclusions about the nature of Allais effect.

1. Some genuinely new dynamical effect should take place when the objects are collinear. If gravitational screening would cause the effect the frequency would always grow but this is not the case.

2. If stellar objects and also ring like dark matter structures possibly assignable to their orbits are Z^0 conductors, one obtains screening effect by polarization and for the ring like structure the resulting effectively 2-D dipole field behaves as $1/\rho^2$ so that there are hopes of obtaining large screening effects and if the Z^0 charge of pendulum is allow to have both signs, one might hope of being to able to explain the effect. It is however difficult to understand why this effect should become so strong in the collinear case.

3. The apparent randomness of the frequency change suggests that interference effect made possible by the gigantic value of gravitational Planck constant is in question. On the other hand, the dependence of $\Delta g/g$ on pendulum suggests a breaking of Equivalence Principle. It however turns out that the variation of the distances of the pendulum to Sun and Moon can explain the experimental findings since the pendulum turns out to act as a sensitive gravitational interferometer. An apparent breaking of Equivalence Principle could result if the effect is partially caused by genuine gauge forces, say dark classical Z^0 force, which can have arbitrarily long range in TGD Universe.

4. If topological light rays (MEs) provide a microscopic description for gravitation and other gauge interactions one can envision these interactions in terms of MEs extending from Sun/Moon radially to pendulum system. What comes in mind that in a collinear configuration the signals along S-P MEs and M-P MEs superpose linearly so that amplitudes are

summed and interference terms give rise to an anomalous effect with a very sensitive dependence on the difference of S-P and M-P distances and possible other parameters of the problem. One can imagine several detailed variants of the mechanism. It is possible that signal from Sun combines with a signal from Earth and propagates along Moon-Earth ME or that the interferences of these signals occurs at Earth and pendulum.

5. Interference suggests macroscopic quantum effect in astrophysical length scales and thus gravitational Planck constants given by $\hbar_{gr} = GMm/v_0$, where $v_0 = 2^{-11}$ is the favored value, should appear in the model. Since $\hbar_{gr} = GMm/v_0$ depends on both masses this could give also a sensitive dependence on mass of the pendulum. One expects that the anomalous force is proportional to $\hbar_{gr}$ and is therefore gigantic as compared to the effect predicted for the ordinary value of Planck constant.

2.3.2 Model for interaction via gravitational MEs with large Planck constant

Restricting the consideration for simplicity only gravitational MEs, a concrete model for the situation would be as follows.

1. The picture based on topological light rays suggests that the gravitational force between two objects M and m has the following expression

$$
\begin{aligned}
F_{M,m} &= \frac{GMm}{r^2} = \int |S(\lambda,r)|^2 p(\lambda) d\lambda \\
p(\lambda) &= \frac{\hbar_{gr}(M,m) 2\pi}{\lambda} \ , \ \hbar_{gr} = \frac{GMm}{v_0(M,m)} \ .
\end{aligned} \tag{2.11}
$$

$p(\lambda)$ denotes the momentum of the gravitational wave propagating along ME. v_0 can depend on (M,m) pair. The interpretation is that $|S(\lambda,r)|^2$ gives the rate for the emission of gravitational waves propagating along ME connecting the masses, having wave length λ, and being absorbed by m at distance r.

2. Assume that $S(\lambda,r)$ has the decomposition

$$
\begin{aligned}
S(\lambda,r) &= R(\lambda) exp\left[i\Phi(\lambda)\right] \frac{exp\left[ik(\lambda)r\right]}{r} \ , \\
exp\left[ik(\lambda)r\right] &= exp\left[ip(\lambda)r/\hbar_{gr}(M,m)\right] \ , \\
R(\lambda) &= |S(\lambda,r)| \ .
\end{aligned} \tag{2.12}
$$

The phases $exp(i\Phi(\lambda))$ might be interpreted in terms of scattering matrix. The simplest assumption is $\Phi(\lambda) = 0$ turns out to be consistent with the experimental findings. The substitution of this expression to the above formula gives the condition

$$
\int |R(\lambda)|^2 \frac{d\lambda}{\lambda} = v_0 \ . \tag{2.13}
$$

Consider now a model for the Allais effect based on this picture.

1. In the non-collinear case one obtains just the standard Newtonian prediction for the net forces caused by Sun and Moon on the pendulum since $Z_{S,P}$ and $Z_{M,P}$ correspond to non-parallel MEs and there is no interference.

2. In the collinear case the interference takes place. If interference occurs for identical momenta, the interfering wavelengths are related by the condition

$$
p(\lambda_{S,P}) = p(\lambda_{M,P} \ . \tag{2.14}
$$

This gives

$$\frac{\lambda_{M,P}}{\lambda_{S,P}} = \frac{\hbar_{M,P}}{\hbar_{S,P}} = \frac{M_M}{M_S}\frac{v_0(S,P)}{v_0(M,P)} \ . \quad (2.15)$$

3. The net gravitational force is given by

$$\begin{aligned} F_{gr} &= \int |Z(\lambda, r_{S,P}) + Z(\lambda/x, r_{M,P})|^2 p(\lambda) d\lambda \\ &= F_{gr}(S,P) + F_{gr}(M,P) + \Delta F_{gr} \ , \\ \Delta F_{gr} &= 2\int Re\left[S(\lambda, r_{S,P})\overline{S}(\lambda/x, r_{M,P}))\right] \frac{\hbar_{gr}(S,P)2\pi}{\lambda} d\lambda \ , \\ x &= \frac{\hbar_{S,P}}{\hbar_{M,P}} = \frac{M_S}{M_M}\frac{v_0(M,P)}{v_0(S,P)} \ . \end{aligned} \quad (2.16)$$

Here $r_{M,P}$ is the distance between Moon and pendulum. The anomalous term ΔF_{gr} would be responsible for the Allais effect and change of the frequency of the oscillator.

4. The anomalous gravitational acceleration can be written explicitly as

$$\begin{aligned} \Delta a_{gr} &= 2\frac{GM_S}{r_S r_M}\frac{1}{v_0(S,P)} \times I \ , \\ I &= \int R(\lambda)R(\lambda/x) cos\left[\Phi(\lambda) - \Phi(\lambda/x) + 2\pi\frac{(y_S r_S - x y_M r_M)}{lambda}\right]\frac{d\lambda}{\lambda} \ , \\ y_M &= \frac{r_{M,P}}{r_M} \ , \ y_S = \frac{r_{S,P}}{r_S} \ . \end{aligned} \quad (2.17)$$

Here the parameter y_M (y_S) is used express the distance $r_{M,P}$ ($r_{S,P}$) between pendulum and Moon (Sun) in terms of the semi-major axis r_M (r_S)) of Moon's (Earth's) orbit. The interference term is sensitive to the ratio $2\pi(y_S r_S - x y_M r_M)/\lambda$. For short wave lengths the integral is expected to not give a considerable contribution so that the main contribution should come from long wave lengths. The gigantic value of gravitational Planck constant and its dependence on the masses implies that the anomalous force has correct form and can also be large enough.

5. If one poses no boundary conditions on MEs the full continuum of wavelengths is allowed. For very long wave lengths the sign of the cosine terms oscillates so that the value of the integral is very sensitive to the values of various parameters appearing in it. This could explain random looking outcome of experiments measuring $\Delta f/f$. One can also consider the possibility that MEs satisfy periodic boundary conditions so that only wave lengths $\lambda_n = 2r_S/n$ are allowed: this implies $sin(2\pi y_S r_S/\lambda) = 0$. Assuming this, one can write the magnitude of the anomalous gravitational acceleration as

$$\begin{aligned} \Delta a_{gr} &= 2\frac{GM_S}{r_{S,P} r_{M,P}} \times \frac{1}{v_0(S,P)} \times I \ , \\ I &= \sum_{n=1}^{\infty} R(\frac{2r_{S,P}}{n}) R(\frac{2r_{S,P}}{nx})(-1)^n cos\left[\Phi(n) - \Phi(xn) + n\pi\frac{x y_M}{y_S}\frac{r_M}{r_S}\right] \ . \end{aligned} \quad (2.18)$$

If $R(\lambda)$ decreases as λ^k, $k > 0$, at short wavelengths, the dominating contribution corresponds to the lowest harmonics. In all terms except cosine terms one can approximate $r_{S,P}$ *resp.* $r_{M,P}$ with r_S *resp.* r_M.

6. The presence of the alternating sum gives hopes for explaining the strong dependence of the anomaly term on the experimental arrangement. The reason is that the value of xyr_M/r_S appearing in the argument of cosine is rather large:

$$\frac{xy_M}{y_S}\frac{r_M}{r_S} = \frac{y_M}{y_S}\frac{M_S}{M_M}\frac{r_M}{r_S}\frac{v_0(M,P)}{v_0(S,P)} \simeq 6.95671837\times 10^4 \times \frac{y_M}{y_S} \times \frac{v_0(M,P)}{v_0(S,P)} \quad .$$

The values of cosine terms are very sensitive to the exact value of the factor $M_S r_M/M_M r_S$ and the above expression is probably not quite accurate value. As a consequence, the values and signs of the cosine terms are very sensitive to the values of y_M/y_S and $\frac{v_0(M,P)}{v_0(S,P)}$.

The value of y_M/y_S varies from experiment to experiment and this alone could explain the high variability of $\Delta f/f$. The experimental arrangement would act like interferometer measuring the distance ratio $r_{M,P}/r_{S,P}$. Hence it seems that the condition

$$\frac{v_0(S,P)}{v_0(M,P)} \neq const. \tag{2.19}$$

implying breaking of Equivalence Principle is not necessary to explain the variation of the sign of $\Delta f/f$ and one can assume $v_0(S,P) = v_0(M,P) \equiv v_0$. One can also assume $\Phi(n) = 0$.

2.3.3 Scaling law

The assumption of the scaling law

$$R(\lambda) = R_0(\frac{\lambda}{\lambda_0})^k \tag{2.20}$$

is very natural in light of conformal invariance and masslessness of gravitons and allows to make the model more explicit. With the choice $\lambda_0 = r_S$ the anomaly term can be expressed in the form

$$\begin{aligned} \Delta a_{gr} &\simeq \frac{GM_S}{r_S r_M}\frac{2^{2k+1}}{v_0}(\frac{M_M}{M_S})^k R_0(S,P)R_0(M,P) \times \sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}}cos\left[\Phi(n)-\Phi(xn)+n\pi K\right] \quad , \\ K &= x\times\frac{r_M}{r_S}\times\frac{y_M}{y_S} \quad . \end{aligned} \tag{2.21}$$

The normalization condition of Eq. 2.13 reads in this case as

$$R_0^2 = v_0 \times \frac{1}{2\pi\sum_n(\frac{1}{n})^{2k+1}} = \frac{v_0}{\pi\zeta(2k+1)} \quad . \tag{2.22}$$

Note the shorthand $v_0(S/M,P) = v_0$. The anomalous gravitational acceleration is given by

$$\begin{aligned} \Delta a_{gr} &= \sqrt{\frac{v_0(M,P)}{v_0(S,P)}}\frac{GM_S}{r_S^2} \times XY \times \sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}}cos\left[\Phi(n)-\Phi(xn)+n\pi K\right] \quad , \\ X &= 2^{2k}\times\frac{r_S}{r_M}\times(\frac{M_M}{M_S})^k \quad , \\ Y &= \frac{1}{\pi\sum_n(\frac{1}{n})^{2k+1}} = \frac{1}{\pi\zeta(2k+1)} \quad . \end{aligned} \tag{2.23}$$

It is clear that a reasonable order of magnitude for the effect can be obtained if k is small enough and that this is essentially due to the gigantic value of gravitational Planck constant.

k	1	1/2	1/4
$\frac{\Delta g}{gcos(\Theta)}$	1.1×10^{-9}	4.3×10^{-6}	1.97×10^{-4}

Table 2: Table gives overall magnitudes of the effect for $k = 1, 2/2$ and $1/4$ as predicted by the model.

The simplest model consistent with experimental findings assumes $v_0(M,P) = v_0(S,P)$ and $\Phi(n) = 0$ and gives

$$\begin{aligned} \frac{\Delta a_{gr}}{gcos(\Theta)} &= \frac{GM_S}{r_S^2 g}\times XY\times\sum_{n=1}^{\infty}\frac{(-1)^n}{n^{2k}}cos(n\pi K) \ , \\ X &= 2^{2k}\times\frac{r_S}{r_M}\times(\frac{M_M}{M_S})^k \ , \\ Y &= \frac{1}{\pi\sum_n(\frac{1}{n})^{2k+1}} = \frac{1}{\pi\zeta(2k+1)} \ , \\ K &= x\times\frac{r_M}{r_S}\times\frac{y_M}{y_S} \ , \ x = \frac{M_S}{M_M} \ . \end{aligned} \tag{2.24}$$

2.3.4 Numerical estimates

To get a numerical grasp to the situation one can use $M_S/M_M \simeq 2.71\times 10^7$, $r_S/r_M \simeq 389.1$, and $(M_S r_M/M_M r_S) \simeq 1.74\times 10^4$. The overall order of magnitude of the effect would be

$$\begin{aligned} \frac{\Delta g}{g} \sim XY\times\frac{GM_S}{R_S^2 g}cos(\Theta) \ , \\ \frac{GM_S}{R_S^2 g} \simeq 6\times 10^{-4} \ . \end{aligned} \tag{2.25}$$

The overall magnitude of the effect is determined by the factor XY.

1. For $k = 0$ the normalization factor is proportional to $1/\zeta(1)$ and diverges and it seems that this option cannot work.

2. **Table 2** gives the predicted overall magnitudes of the effect for $k = 1, 2/2$ and $1/4$.

   For $k = 1$ the effect is too small to explain even the findings of [E20] since there is also a kinematic reduction factor coming from $cos(\Theta)$. Therefore $k < 1$ suggesting fractal behavior is required. For $k = 1/2$ the effect is of same order of magnitude as observed by Allais. The alternating sum equals in a good approximation to -.693 for $y_S/y_M = 1$ so that it is not possible to explain the finding $\Delta f/f \simeq 5\times 10^{-4}$ of Jeverdan.

3. For $k = 1/4$ the expression for Δa_{gr} reads as

$$\begin{aligned} \frac{\Delta a_{gr}}{gcos(\Theta)} &\simeq 1.97\times 10^{-4}\sum_{n=1}^{\infty}\frac{(-1)^n}{n^{1/2}}cos(n\pi K) \ , \\ K &= \frac{y_M}{y_S}u \ , \ u = \frac{M_S}{M_M}\frac{r_M}{r_S} \simeq 6.95671837\times 10^4 \ . \end{aligned} \tag{2.26}$$

   The sensitivity of cosine terms to the precise value of y_M/y_S gives good hopes of explaining the strong variation of $\Delta f/f$ and also the findings of Jeverdan. Numerical experimentation indeed shows that the cosine sum alternates and increases as y_M/y_S increases in the range $[1, 2]$.

The eccentricities of the orbits of Moon *resp.* Earth are $e_M = .0549$ *resp.* $e_E = .017$. Denoting semimajor and semiminor axes by a and b one has $\Delta = (a-b)/a = 1-\sqrt{1-e^2}$. $\Delta_M = 15\times 10^{-4}$ *resp.* $\Delta_E = 1.4\times 10^{-4}$ characterizes the variation of y_M *resp.* y_M due to the non-circularity of the orbits of Moon *resp.* Earth. The ratio $R_E/r_M = .0166$ characterizes the range of the variation of $\Delta y_M = \Delta r_{M,P}/r_M \leq R_E/r_M$ due to the variation of the position of the laboratory. All these numbers are large enough to imply large variation of the argument of cosine term even for $n = 1$ and the variation due to the position at the surface of Earth is especially large.

The duration of full eclipse is of order 8 minutes which corresponds to angle $\phi = \pi/90$ and at equator roughly to a $\Delta y_N = (\sqrt{r_M^2 + R_E^2 sin^2(\pi/90)} - r_M)/r_M \simeq (\pi/90)^2 R_E^2/2r_M^2 \simeq 1.7\times 10^{-7}$. Thus the change of argument of $n = 1$ cosine term during full eclipse is of order $\Delta\Phi = .012\pi$ at equator. The duration of the eclipse itself is of order two 2 hours giving $\Delta y_M \simeq 3.4\times 10^{-5}$ and the change $\Delta\Phi = 2.4\pi$ of the argument of $n = 1$ cosine term.

2.3.5 Other effects

There are also other strange effects involved.

1. One should explain also the recent finding by Popescu and Olenici, which they interpret as a quantization of the plane of oscillation of paraconical oscillator during solar eclipse [E25]. A possible TGD based explanation would be in terms of quantization of $\Delta\overline{g}$ and thus of the limiting oscillation plane. This quantization could reflect the quantization of the angular momentum of the dark gravitons decaying into bunches of ordinary gravitons and providing to the pendulum the angular momentum inducing the change of the oscillation plane. The knowledge of friction coefficients associated with the rotation of the oscillation plane would allow to deduce the value of the gravitational Planck constant if one assumes that each dark gravitons corresponds to its own approach to asymptotic oscillation plane. The flux would be reduced in a stepwise manner during the solar eclipse as the distance traversed by the flux through Moon increases and reduced in a similar manner after the maximum of the eclipse.

2. There is also evidence for the effect before and after the main eclipse [E25]. The time scale is 1 hour. A possible explanation is in terms of a dark matter ring analogous to rings of Jupiter surrounding Moon. From the average orbital velocity $v = 1.022$ km/s of the Moon one obtains that the distance traversed by moon during 1 hour is $R_1 = 3679$ km. The mean radius of moon is $R = 1737.10$ km so that one has $R_1 = 2R$ with 5 per cent accuracy ($2\times R = 3474$ km). The Bohr quantization of the orbits of the inner planets discussed in [K7] with the value $\hbar_{gr} = GMm/v_0$ of the gravitational Planck constant predicts $r_n \propto n^2 GM/v_0^2$ and gives the orbital radius of Mercury correctly for the principal quantum number $n = 3$ and $v_0/c = 4.6\times 10^{-4} \simeq 2^{-11}$. From the proportionality $r_n \propto n^2 GM/v_0^2$ one can deduce by scaling that in the case of Moon with $M(moon)/M(Sun) = 3.4\times 10^{-8}$ the prediction for the radius of $n = 1$ Bohr orbit would be $r_1 = (M(Moon)/M(Sun))\times R_M/9 \simeq .0238$ km for the same value of v_0. This is too small by a factor 6.45×10^{-6}. $r_1 = 3679$ km would require $n \sim 382$ or $n = n(Earth) = 5$ and $v_0(Moon)/v_0(Sun) \simeq 2^{-4}$.

2.4 Could Z^0 Force Be Present?

One can understand the experimental results without a breaking of Equivalence Principle if the pendulum acts as a quantum gravitational interferometer. One cannot exclude the possibility that there is also a dependence on pendulum. In this case one would have a breaking of Equivalence Principle, which could be tested using several penduli in the same experimental arrangement. The presence of Z^0 force could induce an apparent breaking of Equivalence Principle. The most plausible option is Z^0 MEs with large Planck constant. One can consider also an alternative purely classical option, which does not involve large values of Planck constant.

2.4.1 Could purely classical Z^0 force allow to understand the variation of $\Delta f/f$?

In the earlier model of the Allais effect (see the Appendix of [K2]) I proposed that the classical Z^0 force could be responsible for the effect. TGD indeed predicts that any object with gravitational mass must have non-vanishing em and Z^0 charges but leaves their magnitude and sign open.

1. If both Sun, Earth, and pendulum have Z^0 charges, one might even hope of understanding why the sign of the outcome of the experiment varies since he ratio of Z^0 charge to gravitational mass and even the sign of Z^0 charge of the pendulum might vary. Constant charge-to-mass ratio is of course the simplest hypothesis so that only an effective scaling of gravitational constant would be in question. A possible test is to use several penduli in the same experiment and find whether they give rise to same effect or not.

2. If Moon and Earth are Z^0 conductors, a Z^0 surface charge canceling the tangential component of Z^0 force at the surface of Earth is generated and affects the vertical component of the force experienced by the pendulum. The vertical component of Z^0 force is $2F_Zcos(\theta)$ and thus proportional to $cos(\Theta)$ as also the effective screening force below the shadow of Moon during solar eclipse. When Sun is in a vertical direction, the induced dipole contribution doubles the radial Z^0 force near surface and the effect due to the gravitational screening would be maximal. For Sun in horizon there would be no Z^0 force and gravitational tidal effect of Sun would vanish in the first order so that over all anomalous effect would be smallest possible: for a full screening $\Delta f/f \simeq \Delta g^2/4g^2 \simeq 4.5\times 10^{-8}$ would be predicted. One might hope that the opposite sign of gravitational and Z^0 contributions could be enough to explain the varying sign of the overall effect.

3. It seems necessary to have a screening effect associated with gravitational force in order to understand the rapid variation of the effect during the eclipse. The fact that the maximum effect corresponds to a maximum gravitational screening suggests that it is present and determines the general scale of variation for the effect. If the maximal Z^0 charge of the pendulum is such that Z^0 force is of the same order of magnitude as the maximal screening of the gravitational force and of opposite sign (that is attractive), one could perhaps understand the varying sign of the effect but the effect would develop continuously and begin before the main eclipse. If the sign of Z^0 charge of pendulum can vary, there is no difficulty in explaining the varying sign of the effect. An interesting possibility is that Moon, Sun and Earth have dark matter halos so that also gravitational screening could begin before the eclipse. The real test for the effect would come from tidal effects unless one can guarantee that the pendulum is Z^0 neutral or its Z^0 charge/mass ratio is always the same.

4. As noticed also by Allais, Newtonian theory does not give a satisfactory account of the tidal forces and there is possibility that tides give a quantitative grasp on situation. If Earth is Z^0 conductor tidal effects should be determined mainly by the gravitational force and modified by its screening whereas Z^0 force would contribute mainly to the pressure waves accompanying the shadows of Moon and Sun. The sign and magnitude of pressure waves below Sun and Moon could give a quantitative grasp of Z^0 forces of Sun and Moon. Z^0 surface charge would have opposite signs at the opposite sides of Earth along the line connecting Earth to Moon *resp.* Sun and depending on sign of Z^0 force the screening and Z^0 force would tend to amplify or cancel the net anomalous effect on pressure.

5. A strong counter argument against the model based on Z^0 force is that collinear configurations are reached in continuous manner from non-collinear ones in the case of Z^0 force and the fact that gravitational screening does not conform with the varying sign of the discontinuous effect occurring during the eclipse. It would seem that the effect in question is more general than screening and perhaps more like quantum mechanical interference effect in astrophysical length scale.

2.4.2 Could Z^0 MEs with large Planck constant be present?

The previous line of arguments for gravitational MEs generalizes in a straightforward manner to the case of Z^0 force. Generalizing the expression for the gravitational Planck constant one has $\hbar_{Z^0} = g_Z^2 Q_Z(M)Q_Z(m)/v_0$. Assuming proportionality of Z^0 charge to gravitational mass one obtains formally similar expression for the Z^0 force as in previous case. If Q_Z/M ratio is constant, Equivalence Principle holds true for the effective gravitational interaction if the sign of Z^0 charge is fixed. The breaking of Equivalence Principle would come naturally from the non-constancy of the $v_0(S,P)/v_0(M,P)$ ratio also in the recent case. The variation of the sign of $\Delta f/f$ would be explained in a trivial manner by the variation of the sign of Z^0 charge of pendulum but this explanation is not favored by Occam's razor.

3 Gravimagnetism And TGD

Gravimagnetism is one of the predictions of GRT which is being tested experimentally. TGD predicts deviations from the predictions of GRT which unfortunately are not seen in the satellite experiment to be discussed below. The claimed discovery of gravimagnetic effect in super-conductors having strength 20 orders of magnitude larger than predicted by GRT raises the question whether TGD might explain the effect.

3.1 Gravity Probe B And TGD

Gravity Probe B experiment tests the predictions o General Relativity related to gravimagnetism. Only the abstract [E14] of the talk C. W. Francis Everitt summarizing the results is available when I am writing this.

The NASA Gravity Probe B (GP-B) orbiting gyroscope test of General Relativity, launched from Vandenberg Air Force Base on 20 April, 2004, tests two consequences of Einstein's theory: 1) the predicted 6.6 arc-s/year geodetic effect due to the motion of the gyroscope through the curved space-time around the Earth; 2) the predicted 0.041 arc-s/year frame-dragging effect due to the rotating Earth. The mission has required the development of cryogenic gyroscopes with drift-rates 7 orders of magnitude better than the best inertial navigation gyroscopes. These and other essential technologies, for an instrument which once launched must work perfectly, have come into being as the result of an intensive collaboration between Stanford physicists and engineers, NASA and industry. GP-B entered its science phase on August 27, 2004 and completed data collection on September 29, 2005. Analysis of the data has been in continuing progress during and since the mission. This paper will describe the main features and challenges of the experiment and announce the first results.

The article [E12] gives an excellent summary of various test of GRT. The predictions tested by GP-B relate to gravimagnetic effects. The field equations of general relativity in post-Newtonian approximation with a choice of a preferred frame can in good approximation ($g_{ij} = -\delta_{ij}$) be written in a form highly reminiscent of Maxwell's questions with g_{tt} component of metric defining the counterpart of the scalar potential giving rise to gravito-electric field and g_{ti} the counterpart of vector potential giving rise to the gravimagnetic field.

Rotating body generates a gravimagnetic field so that bodies moving in the gravimagnetic field of a rotating body experience the analog of Lorentz force and gyroscope suffers a precession similar to that suffered by a magnetic dipole in magnetic field (Thirring-Lense effect or frame-drag). Besides this there is geodetic precession due to the motion of the gyroscope in the gravito-electric field present even in the case of non-rotating source which might be perhaps understood in terms of gravito-Faraday law. Both these effects are tested by GP-B.

In the following I represent some general comments about how TGD and GRT differs and also say something about the predictions of TGD concerning GP-B experiment.

3.1.1 TGD and GRT

Consider first basic differences between TGD and GRT.

1. In TGD local Lorentz invariance is replaced by exact Poincare invariance at the level of the embedding space $H = M^4 \times CP_2$. Hence one can use unique global Minkowski coordinates for the space-time sheets and gets rids of the problems related to the physical identification of the preferred coordinate system.

2. General coordinate invariance holds true in both TGD and GRT.

3. The basic difference between GRT and TGD is that in TGD framework gravitational field is induced from the metric of the embedding space. One important cosmological implication is that the embeddings of the Robertson-Walker metric for which the gravitational mass

density is critical or overcritical fail after some value of cosmic time. Also classical gauge potentials are induced from the spinor connection of H so that the geometrization applies to all classical fields. Very strong constraints between fundamental interactions at the classical level are implied since CP_2 are the fundamental dynamical variables at the level of macroscopic space-time.

4. Equivalence Principle (EP) holds in classical sense for the GRT limit of TGD understood as effective theory with effective space-time in long length scales defined as M^4 endowed with an effective metric defined as the sum of Minkowski metric and sum of deviations from Minkowski metric for various space-time sheets involved. Thus GRT space-time lumps together the space-time sheets of many-sheeted spacetime and there is always a length scale resolution involved. EP reduces to Einstein's equations and reflects underlying Poincare invariance.

   In Zero Energy Ontology (ZEO) zero energy states and corresponding space-time surfaces reside always inside some causal diamond (CD) characterized by scale. Therefore the conserved four-momentum assingable to either end of CD is scale dependent quantity, and the apparent non-conservation of four-momentum as scale is changed is not in conflict with Poincare invariance.

   At the quantum level EP would hold true in the sense that classical Noether charges in the Cartan algebra of isometries and associated with Kähler action are equal to the eigenvalues of the quantal charges of Kähler-Dirac action: EP would reduce to Quantum classical correspondence. Holography allows to consider also the possibility that gravitational and inertial charges correspond to those assignable to light-like and space-like 3-surfaces respectively.

3.1.2 TGD and GP-B

There are excellent reasons to expect that Maxwellian picture holds true in a good accuracy if one uses Minkowski coordinates for the space-time surface. In fact, TGD allows a static solutions with 2-D CP_2 projection for which the prerequisites of the Maxwellian interpretation are satisfied (the deviations of the spatial components g_{ij} of the induced metric from $-\delta_{ij}$ are negligible).

Schwartschild and Reissner-Norström metrics allow embeddings as 4-D surfaces in H but Kerr metric [E7] assigned to rotating systems probably not. If this is indeed the case, the gravimagnetic field of a rotating object in TGD Universe cannot be identical with the exact prediction of GRT but could be so in the Post-Newtonian approximation. Scalar and vector potential correspond to four field quantities and the number of CP_2 coordinates is four. Embedding as vacuum extremals with 2-D CP_2 projection guarantees automatically the consistency with the field equations but requires the orthogonality of gravito-electric and -magnetic fields. This holds true in post-Newtonian approximation in the situation considered.

Hence apart from restrictions caused by the failure of the global embedding at short distances it *might* be possible to imbed Post-Newtonian approximations into H in the approximation $g_{ij} = -\delta_{ij}$. If so, the predictions for Thirring-Lense effect would not differ measurably from those of GRT. The predictions for the geodesic precession involving only scalar potential would be identical in any case.

The imbeddability in the post-Newtonian approximation is however questionable if one assumes vacuum extremal property and small deformations of Schwartschild metric indeed predict a gravimagnetic field differing from the dipole form.

1. Simplest candidate for the metric of a rotating star

The simplest situation for the metric of rotating start is obtained by assuming that vacuum extremal imbeddable to $M^4 \times S^2$, where S^2 is the geodesic sphere of CP_2 with vanishing homological charge and induce Kähler form. Use coordinates (Θ, Φ) for S^2 and spherical coordinates (t, r, θ, ϕ) in space-time identifiable as M^4 spherical coordinates apart from scaling and r-dependent shift in the time coordinate.

1. For Schwartschild metric one has

$$\Phi = \omega t \ , \ sin(\Theta) = f(r) \ . \tag{3.1}$$

f is fixed highly uniquely by the embedding of Schwartschild metric and asymptotically one must have

$$f = f_0 + \frac{C}{r}$$

in order to obtain $g_{tt} = 1 - 2GM/r$ $(\equiv 1 + \Phi_{gr})$ behavior for the induced metric.

2. The small deformation giving rise to the gravimagnetic field and metric of rotating star is given by

$$\Phi = \omega t + n\phi \quad (3.2)$$

There is obvious analogy with the phase of Schödinger amplitude for angular momentum eigenstate with $L_z = n$ which conforms with the quantum classical correspondence.

3. The non-vanishing component of A^g is proportional to gravitational potential Φ_{gr}

$$A^g_\phi = g_{t\phi} = (n/\omega)\Phi_{gr} \ . \quad (3.3)$$

4. A little calculation gives for the magnitude of B^θ_g from the curl of A^g the expression

$$B^\theta_g = \frac{n}{\omega} \times \frac{1}{sin(\theta)} \times \frac{2GM}{r^3} \ . \quad (3.4)$$

In the plane $\theta = \pi/2$ one has dipole field and the value of n is fixed by the value of angular momentum of star.

5. Quantization of angular momentum is obtained for a given value of ω. This becomes clear by comparing the field with dipole field in $\theta = \pi/2$ plane. Note that GJ, where J is angular momentum, takes the role of magnetic moment in B_g [E12] appears as a free parameter analogous to energy in the embedding and means that the unit of angular momentum varies. In TGD framework this could be interpreted in terms of dynamical Planck constant having in the most general case any rational value but having a spectrum of number theoretically preferred values. Dark matter is interpreted as phases with large value of Planck constant which means possibility of macroscopic quantum coherence even in astrophysical length scales. Dark matter would induce quantum like effects on visible matter. For instance, the periodicity of small n states might be visible as patterns of visible matter with discrete rotational symmetry.

2. Comparison with the dipole field

The simplest candidate for the gravimagnetic field differs in many respects from a dipole field.

1. Gravitomagnetic field has $1/r^3$ dependence so that the distance dependence is same as in GRT.

2. Gravitomagnetic flux flows along z-axis in opposite directions at different sides of $z = 0$ plane and emanates from z-axis radially and flows along spherical surface. Hence the radial component of B_g would vanish whereas for the dipole field it would be proportional to $cos(\theta)$.

3. The dependence on the angle θ of spherical coordinates is $1/sin(\theta)$ (this conforms with the radial flux from z-axis whereas for the dipole field the magnitude of B^θ_g has the dependence $sin(\theta)$. At $z = 0$ plane the magnitude and direction coincide with those of the dipole field so that satellites moving at the gravimagnetic equator would not distinguish between GRT and TGD since also the radial component of B_g vanishes here.

4. For other orbits effects would be non-trivial and in the vicinity of the flux tube formally arbitrarily large effects are predicted because of $1/sin(\theta)$ behavior whereas GRT predicts $sin(\theta)$ behavior. Therefore TGD could be tested using satellites near gravito-magnetic North pole.

5. The strong gravimagnetic field near poles causes gravi-magnetic Lorentz force and could be responsible for the formation of jets emanating from black hole like structures. This additional force might have also played some role in the formation of planetary systems and the plane in which planets move might correspond to the plane $\theta = \pi/2$ where gravimagnetic force has no component orthogonal to the plane. Same applies in the case of galaxies.

3. Consistency with the model for the asymptotic state of star

In TGD framework natural candidates for the asymptotic states of the star are solutions of field equations for which gravitational four-momentum is locally conserved. Vacuum extremals must therefore satisfy the field equations resulting from the variation of Einstein's action (possibly with cosmological constant) with respect to the induced metric. Quite remarkably, the solution representing asymptotic state of the star is necessarily rotating.

The proposed picture is consistent with the model of the asymptotic state of star. Also the magnetic parts of ordinary gauge fields have essentially similar behavior. This is actually obvious since CP_2 coordinates are fundamental dynamical variables and the field line topologies of induced gauge fields and induced metric are therefore very closely related.

As already discussed, the physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity [E30, E18, E19]. Hence there are some reasons to think that gravimagnetic fields might have a surprise in store.

When I am writing this (day later than what is above I have learned that the error bars for the frame-dragging effect are still twice the size of the effect as predicted by GRT. Already this information would have killed TGD inspired model unless the satellite would have been at the equator.

3.2 Does Horizon Correspond To A Degenerate Four-Metric For The Rotating Counterpart Of Schwartshild Metric?

The metric determinant at Schwartschild radius is non-vanishing. This does not quite conform with the interpretation as an analog of a light-like partonic 3-surface identifiable as a wormhole throat for which the determinant of the induced 4-metric vanishes and at which the signature of the induced metric changes from Minkowskian to Euclidian.

An interesting question is what happens if one makes the vacuum extremal representing embedding of Schwartshild metric a rotating solution by a very simple replacement $\Phi \to \Phi + n\phi$, where Φ is the angle angle coordinate of homologically trivial geodesic sphere S^2 for the simplest vacuum extremals, and ϕ the angle coordinate of M^4 spherical coordinates. It turns out that Schwartschild horizon is transformed to a surface at which $det(g_4)$ vanishes so that the interpretation as a wormhole throat makes sense.

The modification implies that the components $g_{t\phi}$ and $g_{r\phi}$ of the Schwartschild metric become non-vanishing and $g_{\phi\phi}$ component receives a small modification. Using the notations of the subsection *"Embedding of Reissner-Nordström metric"* , one has

$$\begin{aligned} g_{t\phi} &= \omega_1 n \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ , \\ g_{r\phi} &= \partial_{r_M} f n \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ , \\ \Delta g_{\phi\phi} &= n^2 \times \frac{R^2}{4} s^{eff}_{\phi\phi} \ . \end{aligned} \tag{3.5}$$

It is easy to see that $g_{r\phi}/g_{t\phi}$ is of order $\sqrt{r_S/r}$, $r_S = 2GM$, so that in an excellent approximation $g_{r\phi} = 0$ holds true at large distances and previous considerations related to gravimagnetic fields remain true.

The vanishing of the 4-D metric determinant reduces to that for 3-D metric determinant $det(g_3)$ associated with (t, r, ϕ). In the case of the Scwartshild metric this determinant is given by

$$
\begin{aligned}
det(g_3) &= -g_{\phi\phi} - Ag_{r\phi}^2 + \frac{g_{t\phi}^2}{A} \ , \\
A &= 1 - \frac{2GM}{r} \equiv 1 - u \ .
\end{aligned}
\tag{3.6}
$$

Since A changes sign at Schwartchild radius $r_s = 2GM$, the determinant can indeed vanish near r_s. In a good approximation can neglect the contribution of $g_{r\phi}$ in the equation and put $r = r_S$ in the slowly varying functions. This gives

$$
\frac{R^2}{4}\omega_1^2 s_{\phi\phi}^{eff} \simeq \lambda^2
\tag{3.7}
$$

from the condition $u = r_S/r = 1$ applied to the induced metric. This gives

$$
\begin{aligned}
g_{\phi\phi} &\simeq -r_S^2 sin^2(\theta) - \frac{n^2}{\omega^2}\lambda^2 \ , \\
g_{t\phi} &\simeq -\frac{n}{\omega}\lambda^2 \ .
\end{aligned}
\tag{3.8}
$$

The singular surface for which $det(g_3)$ vanishes satisfies the approximate equation

$$
u - 1 = \frac{g_{t\phi}^2}{g_{\phi\phi}}(r = r_S) = \frac{n^2\lambda^4}{\omega^2 r_S^2 sin^2(\theta) - n^2\lambda^2} \ .
\tag{3.9}
$$

Since the left hand side can have both signs, the solution certainly exists but it can happen that part of it is inside and part outside Schwartshild radius.

$\theta = 0$ allows solution only for $r > r_S$: hence some portion of the surface is always outside r_S. If the condition

$$
\lambda^2 > \frac{\omega^2 r_S^2}{n^2}
\tag{3.10}
$$

is satisfied, the surface belongs belongs as a whole to the region $r > r_S$. The singular surface has a cigar like shape approaching sphere $r = \lambda^2 r_S$, $\lambda > 1$ at large quantum number limit $n \rightarrow \infty$. For $n = 0$ no solution is obtained. If one assumes that black hole horizon is analogous to a wormhole contact, only rotating black hole like structures with quantized angular momentum are possible in TGD Universe.

3.3 Has Strong Gravimagnetism Been Observed?

Physicists M. Tajmar and C. J. Matos and their collaborators working in ESA (European Satellite Agency) have made an amazing claim of having detected strong gravimagnetism with gravimagnetic field having a magnitude which is about 20 orders of magnitude higher than predicted by General Relativity [E18]. If the findings are replicable they mean a revolution in the science of gravity and, as one might hope, force a long-waited serious reconsideration of the basic assumptions of the dominating super-string approach.

The starting point of the theory is the so called Thomson magnetic moment generated in rotating charged super-conductors adding a constant contribution to the exponentially damped Meissner contribution to the magnetic field. This contribution can be understood as being due to the massivation of photons in super-conductors. The modified Maxwell equations are obtained by just adding scalar potential mass term to Gauss law and vector potential mass term to the equation related the curl of the magnetic field to the em current.

The expression for the Thomson magnetic field is given by

$$B = 2\omega_R n_s \times \lambda_\gamma^2 \ , \tag{3.11}$$

where ω_R is the angular velocity of superconductor, n_s is charge density of super-conducting particles and $\lambda_\gamma = \hbar/m_\gamma$ is the wave length of a massive photon at rest. In the case of ordinary superconductor one has $\lambda_\gamma = \sqrt{m^*/q^* n_s}$, where $m^* \simeq 2m_e$ and $q^* = -2e$ are the mass and charge of Cooper pair. Hence one has

$$B = -2\frac{m^*}{2e}\omega_R \ . \tag{3.12}$$

Magnetic field extends also outside the super-conductor and by measuring it with a sufficient accuracy outside the super-conductor one can determine the value of the electron mass. Instead of the theoretical value $m^*/2m_e = .999992$ which is smaller than one due to the binding energy of the Cooper pair the value $m^*/2m_e = 1.000084$ was found by Tate [E19]. This inspired the theoretical work generalizing the notion of Thomson field to gravimagnetism and the attempt to explain the anomaly in terms of the effects caused by the gravimagnetic field.

Note that in the case of ordinary matter the equations would lead to an inconsistency at the limit $m_\gamma = 0$ since the value of Thomson magnetic field would become infinite. The resolution of the problem proposed in [E30] is based on the replacement of rotation frequency ω with electron's spin precession frequency $\omega_L = -eB/2m$ so that the consistency equation becomes $B = -B = 0$ for a unique choice $1/\lambda_\gamma^2 = -\frac{q}{m}n$. One could also consider the replacement of ω with electron's cyclotron frequency $\omega_c = 2\omega_L$. To my opinion there is no need to assume that the modified Maxwell's equations hold true in the case of ordinary matter.

3.3.1 Gravimagnetic field

The perturbative approach to the Einstein equations leads to equations which are essentially identical with Maxwell's equations. The g_{tt} component of the metric plays the role of scalar potential and the components g_{ti} define gravitational vector potential. Also the generalization to the super-conducting situation in which graviphotons develop a mass is straightforward. Just add the scalar potential mass term to the counterpart of Gauss law and vector potential mass term to the equation relating the curl of the gravimagnetic field to the gravitational mass current.

In the case of a rotating superconductor Thomson magnetic moment is replaced with its gravimagnetic counterpart

$$B_{gr} = -2\omega_R \rho_m \lambda_g^2 \ . \tag{3.13}$$

Obviously this formula would give rise to huge gravimagnetic fields in ordinary matter approaching infinite values at the limit of vanishing gravitational mass. Needless to say, these kind of fields have not been observed.

Equivalence Principle however suggests that the gravimagnetic field must be assigned with the rotating coordinate frame of the super-conductor. Equivalence principle would state that seing the things in a rotating reference frame is equivalent of being in a gravimagnetic field $B_{gr} = -2\omega_R$ in the rest frame. This fixes the graviphoton mass to

$$\frac{1}{\lambda_{gr}^2} = (\frac{m_{gr}}{\hbar})^2 = G\rho_m \ . \tag{3.14}$$

For a typical condensed matter density parameterized as $\rho_m = Nm_p/a^3$, $a = 10^{-10}$ m this gives the order of magnitude estimate $m_{gr} \sim N^{1/2}10^{-21}/a$ so that graviton mass would be extremely small.

If this is all what is involved, gravimagnetic field should have no special effects. In [E30] it is however proposed that in superconductors a small breaking of Equivalence Principle occurs. The basic assumptions are following.

1. Super-conducting phase and the entire system obey separately their gravitational analogs of Maxwell field equations.
2. The ad hoc assumption is that for super-conducting phase the sign of the gravimagnetic field is opposite to that for the ordinary matter. If purely kinematic effect were in question so that graviphotons were pure gauge degrees of freedom, the value of m_{gr}^2 should should be proportional to ρ_m and $\rho_m - \rho_m^*$ respectively.
3. Graviphoton mass is same for both ordinary and super-conducting matter and corresponds to the net density ρ_m of matter. This is essential for obtaining the breaking of Equivalence Principle.

With these assumptions the gravimagnetic field giving rise to acceleration field detected in the rest system would be given by

$$B_{gr}^* = \frac{\rho_m^*}{\rho} \times 2\omega \quad (3.15)$$

This is claimed to give rise to a genuine acceleration field

$$g^* = -\frac{\rho_m^*}{\rho} a \quad (3.16)$$

where a is the radial acceleration due to the rotational motion.

3.3.2 Explanation for the too high value of measured electron mass in terms of gravimagnetic field

A possible explanation of the anomalous value of the measured electron mass [E19] is in terms of gravimagnetic field affecting the flux Bohr quantization condition for electrons by adding to the electromagnetic vector potential term q^*A_{em} gravitational vector potential m^*A_{gr}. By requiring that the quantization condition

$$\oint (m^*v + q^*A_{em} + m^*A_{gr})dl = 0 \quad (3.17)$$

is satisfied for the superconducting ring, one obtains

$$B = -\frac{2m}{e}\omega - \frac{m}{e}B_{gr} \ . \quad (3.18)$$

This means that the magnetic field is slightly stronger than predicted and it has been known that this is indeed the case experimentally.

The higher value of the magnetic field could explain the slightly too high value of electron mass as determined from the magnetic field. This gives

$$B_{gr} = \frac{\Delta m_e}{m_e} \times 2\omega = \frac{\Delta m_e}{m_e} \times e m_e \times B \ . \quad (3.19)$$

The measurement implies $\Delta m_e/m_e = 9.2\times10^{-5}$. The model discussed in [E30] predicts $\Delta m_e/m_e \sim \rho^*/\rho$. The prediction is about 23 times smaller than the experimental result.

3.4 Is The Large Gravimagnetic Field Possible In TGD Framework?

TGD allows top consider several alternative solutions for the claimed effect.

1. TGD predicts the possibility of classical electro-weak fields at larger space-time sheets. If these couple to Cooper pairs generate exotic weak charge at super-conducting space-time sheets the Bohr quantization conditions modify the value of the magnetic field. Exotic weak charge would however mean also exotic electronic em charge so that this option is excluded. It would also require that the Z^0 charge of test bodies used to measure the acceleration field is proportional to their gravitational mass.

2. According to the simplest recent view about Kähler-Dirac action [K14] the modes of Dirac operator are confined to 2-D string world sheets at which classical W boson fields vanish. This guarantees that em charge is well-defined for the modes. The stronger condition that also classical Z^0 field vanishes makes also sense and should hold at least in the length scales in which weak bosons do not appear. This guarantees the absence of axial couplings and parity breaking effects. In living matter parity breaking effects are large and one could consider the possibility that weak length scale is scaled up for $h_{eff} > h$ and that classical Z^0 fields are present below the weak scale.

3. One cannot exclude the possibility that the classical weak fields vanish for entire space-time surface. In this case spinor modes can still be seen as continuous superpositions of 2-D ones.In principle one can consider also other options - such as vanishing of induced Kähler form or classical em field besides that of W fields.

The conservative option is that classical weak fields vanish in the situation considered so that there is room for the strong gravimagnetic field.

1. The formula used by Tajmar *et al* [E30] for the gravimagnetic variant of Thomson magnetic field is direct generalization for the Thomson field for ordinary super-conductor. The gravimagnetic field is proportional to the product $B_g = \omega_R r^2$ of the rotation frequency ω_R of super-conductor and square of the ratio $r = (\lambda_g/\lambda_{g,T})$ where $\lambda_g = \hbar/m_g$ is graviton wave length and $\lambda_{g,T}$ is gravimagnetic peneration length obtained as generalization of the magnetic penetration length for super-conductors by replacing charge with mass. The latter is purely classical quantity whereas graviton wave length depends on Planck constant. Graviton mass can be argued to result in gravitational Meissner effect and can be estimated from the value of cosmological constant Λ being essentially its square root. The resulting value of B_g is too small by 28 orders of magnitude.

2. Tajmar *et al* [E30] suggests that graviton mass is larger by a factor of order 10^{14} in conflict with the experimental upper bound of order 10^{55} kg for m_g. TGD proposal is that it is Planck constant which should be replaced with effective Planck constant $h_{eff} = nh$ equal to gravitational Planck constant h_{gr} for electron Cooper pair in Earth's gravitational field. The model for planetary orbits as Bohr orbits together with Equivalence Principle implies $\hbar_{gr} = GMm/v_0$ at flux tubes connecting particle with mass m to Sun with mass M. v_0 has dimensions of velocity and has order of magnitude correlating with a typical rotation velocity of planetary orbit by Bohr quantization rules.

3. In the recent case the rotation velocity v_0 is the rotation velocity of Earth at its surface: $v_0(E)/c = 2.16 \times 10^{-6}$ to be compared with $v_0(S)/c \simeq .5 \times 10^{-3}$ for Sun-Earth system. The scaling of λ_g is given by $h_{gr}(E, pair)/h = (h_{gr,S,pair}/h) \times (M_E/M_S) \times v_0(S)/v_0(E)$. This gives

$$r \equiv \frac{h_{gr,S,pair}}{h} = \frac{\lambda(h_{gr,S,pair}}{\lambda(h,pair)} = \frac{\frac{GM}{v_0(S)}}{\lambda_c(pair)} = \frac{\frac{r_S}{v_0(S)}}{\lambda_c(e)} \ .$$

Using $r_S = 3km$ and $\lambda_e = .243 \times 10^{-12}$ m and $v_0(S) \simeq 2^{-11}$, $M_E/M_S = 3.0 \times 10^{-6}$ one obtains $r \simeq 3.6 \times 10^{14}$. This happens to be correct order of magnitude! Maybe the model might have something to do with reality. Even better, also the value of h_{eff} is consistent with its value spectrum appearing in EEG if one requires that the energy of dark EEG photon with frequency of order 10 Hz is that of biophoton with frequency of about 5×10^14 Hz. If this picture is correct the values of $h_{eff} = h_{gr}$ would comes as proportional to the masses of particles and cyclotron energies proportional to heB/m would not depend on the mass of the particle at all.

4. What is nice that the model unifies the notions of gravitational Planck constant and dark Planck constant. The basic observation is that Equivalence Principle allows to understand the effects of h_{gr} by reducing it to elementary particle level interpreted in terms of flux tubes connecting particle to the bigger system. This allows to avoid gigantic values of h_{gr} and gives connection with TGD inspired quantum biology. The new quantum physics associated with gravitation would also become key part of quantum biology.

4 Some Differences Between GRT And TGD

In the following some effects possibly differentiating between GRT and TGD are discussed.

4.1 Do Neutrinos Travel With Superluminal Speed?

The newest particle physics rumour has been that the CERN OPERA (see `http://tinyurl.com/676bxl8`) team working in Gran Sasso, Italy has reported 6.1 sigma evidence that neutrinos move with a super-luminal speed. The total travel time is measured in milliseconds and the deviation from the speed of the light is nanoseconds meaning $\Delta c/c \simeq 10^{-6}$ which is roughly 10^3 times larger than the uncertainty 4.5×10^{-9} in the measured value of the speed of light (see `http://tinyurl.com/3wdq4`). If the result is true it means a revolution in the fundamental physics. There is now an article by OPERA collaboration [H1] in arXiv (see `http://tinyurl.com/3h44vxw`) so that superluminal neutrinos are not a rumour anymore. Even the finnish tabloid "Iltalehti" reacted to the news and this is really something unheard! Maybe the finding could even stimulate colloquium in physics department of Helsinki University!

The superluminal speed of neutrino has stimulated intense email debates and blog discussions. The reactions to the potential discovery depend on whether the person can imagine some explanation for the finding or not. In the latter case the reaction is denial: most physics bloggers have chosen this option for understandable reasons. What else could they do? Personally I cannot take tachyonic neutrinos seriously but I would not however choose the easy option and argue that the result is due to a bad experimentation as Lubos Motl (see `http://tinyurl.com/3erbfg5`) and Jester (see `http://tinyurl.com/3dll193`) do. The six sigma statistics does not leave much room for objections but there could of course be some very delicate systematical error involved. Lubos Motl (see `http://tinyurl.com/3meymp`) wrote quite an interesting piece about possible errors of this kind and classified the possible errors to timing errors either at CERN or Italy or to errors in distance measurement.

4.1.1 Basic data

The neutrinos used are highly relativistic having average energy 17 GeV much larger than the mass scale of neutrinos of order.1 eV. The distance between CERN and Gran Sasso is roughly 750 km, which corresponds to the time of travel equal to $T = 2.4$ milliseconds. The nasty neutrinos arrived to Gran Sasso $\Delta T = 60.7 \pm 6.9$ (statistical) ± 7.4 (systematic) ns before they should have done so. This time corresponds to a distance $\Delta L = 18$ m. From this is is clear that the distance and timing measurements must be extremely accurate. The claimed distance precision is 20 cm [H1] (see `http://tinyurl.com/3h44vxw`).

Experimentalists tell that they have searched for al possible systematic errors that they are able to imagine. The relative deviation of neutrino speed from the speed of light is

$$\frac{c-v)}{v} = (5.1 \pm 2.9) \times 10^{-5} \quad ,$$

which is much larger than the uncertainty related to the value of the speed of light. The effect does not depend on neutrino energy. 6.1 sigma result is in question so that it can be a statistical fluctuation with probability of 10^{-9} in the case that there is no systematic error.

The result is not the first of this kind and the often proposed interpretation is that neutrinos behave like tachyons. The following is the abstract (see `http://tinyurl.com/ycto3v2z`) of the article [H3] giving a summary about the earlier evidence that neutrinos can move faster than the speed of light.

From a mathematical point of view velocities can be larger than c. It has been shown that Lorentz transformations are easily extended in Minkowski space to address velocities beyond the speed of light. Energy and momentum conservation fixes the relation between masses and velocities larger than c, leading to the possible observation of negative mass squared particles from a standard reference frame. Current data on neutrino mass squared yield negative values, making neutrinos as possible candidates for having speed larger than c. In this paper, an original analysis of the SN1987A supernova data is proposed. It is shown that all the data measured in "87" by all the experiments are consistent with a description of neutrinos as combination of superluminal mass eigenstates. The well known enigma on the arrival times of the neutrino bursts detected at LSD, several hours earlier than at IMB, K2 and Baksan, is explained naturally. It is concluded that experimental evidence for superluminal neutrinos was recorded since the SN1987A explosion, and that data are quantitatively consistent with the introduction of tachyons in Einstein's equation.

4.1.2 TGD inspired model

This kind of effect is actually one of the basic predictions of TGD reflecting the differences between kinematics of relativities based on a view about space-time as abstract manifold and TGD in which one has sub-manifold gravitation and emerged for more than 20 years ago. Also several Hubble constants are predicted and explanation for why the distance between Earth and Moon seems to increasing as an apparent phenomenon emerges. There are many other strange phenomena which find an explanation [K13, K8, K7].

It is sub-manifold geometry which allows to fuse the good aspects of both special relativity (the existence of well-defined conserved quantities due to the isometries of embedding space) and general relativity (geometrization of gravitation in terms of the induced metric). As an additional bonus one obtains a geometrization of the electro-weak and color interactions and of standard model quantum numbers. The choice of the embedding space is unique. The new element is the generalization of the notion of space-time: space-time identified as a four-surface has shape as seen from the perspective of the embedding space $M^4 \times CP_2$. The study of field equations leads among other things to the notion of many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book).

For many-sheeted space-time light velocity is assigned to light-like geodesic of space-time sheet rather than light-like geodesics of embedding space $M^4 \times CP_2$. The effective velocity determined from time to travel from point A to B along different space time sheets is different and therefore also the signal velocity determined in this manner. The light-like geodesics of space-time sheet corresponds in the generic case time-like curves of the embedding space so that the light-velocity is reduced from the maximal signal velocity. Space-time sheet is bumpy and wiggled so that the path is longer. Each space-time sheet corresponds to different light velocity as determined from the travel time. The maximal signal velocity is reached only in an ideal situation when the space-time geodesics are geodesics of Minkowski space.

1. Estimate fro the light velocity from Robertson-Walker cosmology

Robertson-Walker cosmology imbedded as 4-surface (this is crucial!) in $M^4 \times CP_2$ [K8] gives a good estimate for the light velocity in cosmological scales.

1. One can use the relationship

$$\frac{da}{dt} = g_{aa}^{-1/2}$$

relating the curvature radius a of RW cosmology space (equal to M^4 light-cone proper time, the light-like boundary of the cone corresponds to the moment of Big Bang) and cosmic time t appearing in Robertson-Walker line element

$$ds^2 = dt^2 - a^2 d\sigma_3^2 \ .$$

2. If one believes that Einstein's equations in long scales, one obtains

$$\frac{8\pi G}{3} \times \rho = \frac{(g_{aa}^{-1} - 1)}{a^2} \ .$$

One can solve from this equation g_{aa} and therefore get an estimate the cosmological speed of light -call it $c_\#$ as

$$c_\# = (g_{aa})^{1/2} \ .$$

3. By plugging in the estimates

$$a \simeq t \simeq 13.8 \times Gy \ \text{(the actual value is around 10 Gy)} \ ,$$

$$\rho \simeq \frac{5m_p}{m^3} \ \text{(5 protons per cubic meter)} \ ,$$

$$G = 6.7 \times 10^{-11} m^3 kg^{-1} s^{-2} \ ,$$

one obtains the estimate

$$c_\# = (g_{aa})^{1/2} \simeq .73 \ ,$$

What can one conclude from the estimate?

1. The result leaves a lot of room to explain various anomalies (problems with determination of Hubble constant, apparent growth of the Moon-Earth distance indicated by the measurement of distance by laser signal, ...). The effective velocity can depend on the scale of space-time sheet along which the relativistic particles arrive (and thus on distance distinguishing between OPERA experiment and SN1987A, see `http://tinyurl.com/ycto3v2z`), it can depend on the character of ultra relativistic particle (photon, neutrino, electron, ...), etc. The effect is testable by using other relativistic particles -say electrons.

2. The energy independence of the results fits perfectly with the predictions of the model since the neutrinos are relativistic. There can be dependence on length scale: in other words distance scale and this is needed to explain SN1987A -CERN difference in $\Delta c/c$. For SN1987A neutrinos were also relativistic and travelled a distance is L=cT=168, 000 light years and the neutrinos arrived about $\Delta T = 2-3$ hours earlier than photons (see `http://tinyurl.com/ycto3v2z`). This gives $\Delta c/c = \Delta T/T \simeq .8 - 1.2 \times 10^{-6}$ which is considerably smaller than for the recent experiment. Hence the tachyonic model fails but scale and particle dependent maximal signal velocity can explain the findings easily.

3. The space-time sheet along which particles propagate would most naturally correspond to a small deformation of a "massless extremal" ("topological light ray" [K3]) assignable to the particle in question. Many-sheeted space-time could act like a spectroscope forcing each (free) particle type at its own kind of "massless extremal". The effect is predicted to be present for *any* relativistic particle. A more detailed model requires a model for the propagation of the particles having as basic building bricks wormhole throats at which the induced metric changes its signature from Minkowskian to Euclidian: the Euclidian regions have interpretation in terms of lines of generalized Feynman graphs. The presence of wormhole contact between two space-time sheets implies the presence of two wormhole throats carrying fermionic quantum numbers and the massless extremal is deformed in the regions surrounding the wormhole throat. At this stage I am not able to construct detailed model for deformed MEs carrying photons, neutrinos or some other relativistic particles.

2. Can one understand SN1987A-OPERA difference in TGD framework?

The challenge for sub-manifold gravity approach is to understand the SN1987A-OPERA difference qualitatively. Why neutrino (and any relativistic particle) travels faster in short length scales?

1. Suppose that this space-time sheet is massless extremal topologically condensed on a magnetic flux tube thickened from a string like object $X^2\times;Y^2$ subset $M^4 \times CP_2$ to a tube of finite thickness. Suppose that this means that the properties of the magnetic flux tube determine the maximal signal velocity. The longer and less straight the tube, the slower the maximal signal velocity since the light-like geodesic along it is longer in the induced metric (time-like curve in $M^4 \times CP_2$). There is also rotation around the flux lines increasing the path length: see below.

2. For a planar cosmic string (X^2 is just plane of M^4) the maximal signal velocity would be as large as it can be but is expected to be reduced as the flux tube develops 4-D M^4 projection. In thickening process flux is conserved so that B scales as $1/S$, S the transversal area of the flux tube. Magnetic energy per unit length scales as 1/S and energy conservation requires that the length of the flux tube scales up like S during cosmic expansion. Flux tubes become longer and thicker as time passes.

3. The particle -even neutrino!- can rotate along the flux lines of electroweak fields inside the flux tube and this makes the path longer. The thicker/longer the flux tube, - the longer the path- the lower the maximal signal velocity. I emphasize that classical Z^0 and W fields (and also gluon fields!) are the basic prediction of TGD distinguishing it from standard model: again the notion of induced gauge field pops up!

4. Classically the cyclotron radius is proportional to the cyclotron energy. For a straight flux tube there is free relativistic motion in longitudinal degrees of freedom and cyclotron motion in transversal degrees of freedom and one obtains essentially harmonic oscillator like states with degeneracy due to the presence of rotation giving rise to angular momentum as an additional quantum number. If the transversal motion is non-relativistic, the radii of cyclotron orbits are proportional to a square root of integer. In Bohr orbitology one has quantization of the neutrino speeds: wave mechanically the same result is obtained in average sense. Fermi statistics implies that the states are filled up to Fermi energy so that several discrete effective light velocities are obtained. In the case of a relativistic electron the velocity spectrum would be of form

$$c_{eff} = \frac{L}{T} = \frac{c_\#}{\sqrt{1 + n\hbar\frac{eB}{m}}} \quad .$$

Here L denotes the length of the flux tube and T the time taken by a motion along a helical orbit when the longitudinal motion is relativistic and transversal motion non-relativistic. In this case the spectrum for c_{eff} is quasi-continuous. Note that for large values of $\hbar = n\hbar_0$ (in TGD Universe) quasicontinuity is lost and in principle the spectrum might allow to the determination of the value of $\hbar$.

5. Neutrino is a mixture of right-handed and left handed components and right-handed neutrino feels only gravitation where left-handed neutrino feels long range classical Z^0 field. In any case, neutrino as a particle having weakest interactions should travel faster than photon and relativistic electron should move slower than photon. One must be however very cautious here. Also the energy of the relativistic particle matters.

This would be the qualitative mechanism explaining why the neutrinos (and relativistic particles in general) travel faster in short scales. The model can be also made quantitative since the cyclotron motion can be understood quantitatively once the field strength is known.

Here brane-theorists trying to reproduce TGD predictions are in difficulties since the notion of induced gauge field is required besides that of induced metric. Also the geometrization of classical electro-weak gauge fields in terms of the spinor structure of embedding space is needed. It is almost impossible to avoid $M^4 \times CP_2$ and TGD.

3. What about electrons and photons?

If I were a boss at CERN, I would suggest that the experiment should be carried out for relativistic electrons whose detection would be much easier and for which one could use much shorter scale.

1. Could one use both photon and electron signal simultaneously to eliminate the need to measure precisely the distance between points A and B.

2. Can one imagine using mirrors for photons and relativistic electrons and comparing the times for $A \rightarrow B \rightarrow A$?

As a matter fact, there is an old result by electric engineer Obolensky [H2] (see http://tinyurl.com/y83g3lhj) that I have mentioned earlier [?], and which states that in circuits signals seem to travel at superluminal speed. The study continues the tradition initiated by Tesla who started the study of what happens when relays are switched on or off in circuits.

1. The experimental arrangement of Obolensky suggest that part of circuit - the base of the so called Obolensky triangle- behaves as a single coherent quantum unit in the sense that the interaction between the relays defining the ends of the base is instantaneous: the switching of the relay induces simultaneously a signal from both ends of the base.

2. There are electromagnetic signals propagating with velocities c_0 (with values $271 \pm 1.8 \times 10^6$ m/s and $278 \pm 2.2 \times 10^6$ m/s) and $c_1(200.110 \times 10^6$ m/s): these velocities are referred to as Maxwellian velocities and they are below light velocity in vacuum equal to $c = 3 \times 10^8$ m/s. c_0 and c_1 would naturally correspond to light velocities affected by the interaction of light with the charges of the circuit.

3. There is also a signal propagating with a velocity c_2 $((620 \pm 2.7) \times 10^6$ m/s), which is slightly more than twice the light velocity in vacuum. Does the identification $c_2 = c_{max}$, where c_{max} is the maximal signal velocity in $M^4 \times CP_2$, make sense? Could the light velocity c in vacuum correspond to light velocity, which has been reduced from the light velocity $c_\# = .73c_{max}$ in cosmic length scales due to the presence of matter to $c_\# = .48c_{max}$. Note that this interpretation does not require that electrons propagate with a super-luminal speed.

4. If Obolensky's findings are true and interpreted correctly, simple electric circuits might allow the study of many-sheeted space-time in garage!

If these findings survive they will provide an additional powerful empirical support for the notion of many-sheeted space-time and could be for TGD what Mickelson-Morley was for Special Relativity. It is sad that TGD predictions must still be verified via accidental experimental findings. It would be much easier to do the verification of TGD systematically. In any case, Laws of Nature do not care about science policy, and I dare hope that the mighty powerholders of particle physics are sooner or later forced to accept TGD as the most respectable known candidate for a theory unifying standard model and General Relativity.

4. Additional support for TGD view from ICARUS experiment

Tommaso Dorigo [C2] (see http://tinyurl.com/3q79xnb) managed to write the hype of his life about super-luminal neutrinos. This kind of accidents are unavoidable and any blogger sooner or later becomes a victim of such an accident. To my great surprise Tommaso Dorigo described in a completely uncritical and hypeish manner a study by ICARUS group [C7] (see http://tinyurl.com/y7y3wfaj) in Gran Sasso and concluded that it definitely refutes OPERA result. This if of course a wrong conclusion and based on the assumption that special and general relativity hold true as such and neutrinos are genuinely superluminal.

Also Sascha Vongehr [C1] (see http://tinyurl.com/3uk6g7t) wrote about ICARUS as a reaction to Tommaso Dorigo's surprising posting but this was purposely written half-joking hype claiming that ICARUS proves that neutrinos travel the first 18 meters with a velocity at least 10 times higher than c. Sascha also wrote a strong criticism of the recent science establishment. The continual uncritical hyping is leading to the loss of the respectability of science and I cannot but share his views. Also I have written several times about the ethical and moral decline of the science community down to what resembles the feudal system of middle ages in which Big Boys have first night privilege to new ideas: something which I have myself had to experience many times.

What ICARUS did was to measure the energy distribution of muons detected in Gran Sasso. This result is used to claim that OPERA result is wrong. The measured energy distribution is compared with the distribution predicted assuming that Cohen-Glashow interpretation (see `http://tinyurl.com/6bwzcl3`) [C6] is correct. This is an extremely important ad hoc assumption without which the ICARUS demonstration fails completely.

1. Cohen and Glashow assume a genuine super-luminality and argue that this leads to the analog of Cherenkov radiation leading to a loss of neutrino energy: 28.2 GeV at CERN is reduced to average of 12.1 GeV at Gran Sasso. From this model one can predict the energy distribution of muons in Gran Sasso.

2. The figure 2 in Icarus preprint (see `http://arxiv.org/pdf/1110.3763v1`) demonstrates that the distribution assuming now energy loss fits rather well the measured energy distribution of muons. The figure does not show the predicted distribution but the figure text tells that the super-luminal distribution would be much “leaner”, which one can interpret as a poor fit.

3. From this ICARUS concludes that neutrinos cannot have exceeded light velocity. The experimental result of course tells only that neutrinos did not lose energy: about the neutrino velocity it says nothing without additional assumptions.

At the risk of boring the reader I repeat: the fatal assumption is that a genuine super-luminality is in question. The probably correct conclusion from this indeed is that neutrinos would lose their energy during their travel by Cherenkov radiation.

In TGD framework situation is different [L1]. Neutrinos move in excellent approximation velocity which is equal to the maximal signal velocity but slightly below it and without any energy loss. The maximal signal velocity is however higher for a neutrino carrying space-time sheets than those carrying photons- a basic implication sub-manifold gravity. I have explained this in detail in previous postings and in [L1].

The conclusion is that ICARUS experiment supports the TGD based explanation of OPERA result. Note however that at this stage TGD does not predict effective super-luminality but only allows and even slightly suggests it and provides also a possible explanation for its energy independence and dependences on length scale and particle. TGD suggests also new tests using relativistic electrons instead of neutrinos.

It is also important to realize that the apparent neutrino super-luminality -if true- provides only single isolated piece evidence for sub-manifold gravity. The view about space-time as 4-surface permeates the whole physics from Planck scale to cosmology predicting correctly particle spectrum and providing unification of fundamental interactions, it is also in a key role in TGD inspired quantum biology and also in quantum consciousness theory inspired by TGD.

5. OPERA confirms super-luminal velocity of neutrinos

OPERA collaboration has published an eprint Measurement of the neutrino velocity with the OPERA detector in the CNGS beam [C9] (see `http://tinyurl.com/3h44vxw`) providing further support for the claim that neutrinos move faster than photons. Tommaso Dorigo (see `http://tinyurl.com/7te5knu`) describes the improved measurements in this blog. The abstract of the preprint is following.

The OPERA neutrino experiment at the underground Gran Sasso Laboratory has measured the velocity of neutrinos from the CERN CNGS beam over a baseline of about 730 km with much higher accuracy than previous studies conducted with accelerator neutrinos. The measurement is based on high-statistics data taken by OPERA in the years 2009, 2010 and 2011. Dedicated upgrades of the CNGS timing system and of the OPERA detector, as well as a high precision geodesy campaign for the measurement of the neutrino baseline, allowed reaching comparable systematic and statistical *accuracies. An early arrival time of CNGS muon neutrinos with respect to the one computed assuming the speed of light in vacuum of (57.8 ± 7.8 (stat.)+8.3-5.9 (sys.)) ns was measured. This anomaly corresponds to a relative difference of the muon neutrino velocity with respect to the speed of light* $(v-c)/c = (2.37 \pm 0.32$ *(stat.) (sys.))* $\times 10^{-5}$. *The above result, obtained by comparing the time distributions of neutrino interactions and of protons hitting the CNGS target in 10.5 μs long extractions, was confirmed by a test performed using a beam with a short-bunch time-structure allowing to measure the neutrino time of flight at the single interaction level.*

In the new experiment the spacing between pulses was only 3 ns. This implies that pulse shape and duration cannot explain the earlier OPERA result as a measurement error. Effectively one studies individual neutrinos. Pulse shape and size has provided for the main stream theorist a cheap and fast way to explain the observation out from his mindscape. Certainly this finding also kills a large class of explanations for neutrino super-luminality. Of course, one must still keep mind open for some delicate measurement error. Lubos Motl suggests that there is a systematic error in GPS system, other colleagues have not taken this option seriously.

Second new finding is that there is a "jitter" in travel times: the arrival times vary within 50 ms range which corresponds to a distance about 15 m. The shortening of travel times is not however not less than 40 ns from that when neutrinos move with light velocity as the figure (see `http://tinyurl.com/hogr3fd`) that can be found from the posting of Phil Gibbs (see `http://tinyurl.com/o7868kx`) demonstrates [C4]. Is the determination of the arrival time inaccurate? Or does the neutrino velocity have values above minimum velocity larger than c?

1. In TGD framework this could mean that the space-time sheet along which neutrino arrives would vary from neutrino to neutrino. The simplest possibility is that its length varies and velocity is constant: this does not look totally implausible.

2. Also the state of neutrino inside space-time sheet could vary from neutrino to neutrino. Classical long ranged Z^0 fields are one of the basic predictions of TGD and in the earlier posting I proposed that neutrino feels classical Z^0 magnetic field and arrives along cyclotron orbit. This would give a discrete spectrum of arrival velocities as

$$v = \frac{c_{\#}}{[1 + n \times \hbar \times \frac{Q_Z(\nu) g_Z B_Z}{m_\nu}]^{1/2}}$$

   with $n = 0, 1, 2, ...$ For some value of n the velocity would become sub-luminal. If $\hbar$ is large enough, the discrete spectrum could be seen in the arrival times. This spectrum does not however look an attractive explanation for the jitter for which spectrum seems to be above minimum value rather than below maximum value.

6. Answers to questions by Eugen Stefanovich

Eugen Stefanovich made in my blog some questions allowing to bring additional details to the overall picture. The answers should reveal what the questions where.

1. There is no energy dependence. There is particle and scale dependence. There is an argument suggesting that the velocity is higher for neutrinos than for photon and for photon higher than for relativistic electron. The difference between neutrino families is expected to be small if the proposed mechanism based on electroweak interactions is correct: this because of the universality/flavor independence of electroweak interactions.

2. The dependence on the length scale of the orbit should be via p-adic length scale and therefore piecewise constant. This kind of jump would come at half octaves of basic length scale and might be therefore observable. Increasing or decreasing the distance between CERN and receiver by a factor of $\sqrt{2}$ could reveal this effect.

3. The distance between CERN and Gran Sasso is 750 km. If I understood correctly, the distance travelled by neutrinos in MINOS experiment is 734 km) [C3] (see `http://tinyurl.com/yc6f6nyo`). 734 km is slightly above p-adic length scale $L(151+2\times 46) = 2^{46} \times L(151) = 2^{46} \times 10^{-8}$ meters= $L(243)$=703 km. If I take p-adic length scale hypothesis seriously then the result should be the same.

4. In cosmic scales one can estimate maximal signal velocity for photon: a very rough estimate using embedding of Roberston-Walker cosmology as Lorentz invariant 4-surface is 73 per cent from absolute maximum (for light-like geodesic of M^4). For SN1987A neutrinos and photons the velocity difference would be much smaller than in shorter scales suggesting that the deviation from absolute maximum approaches to zero at very long distance scales.

   (a) One possibility is

   $$\Delta[\frac{v}{c}(p] \propto L_p^{-n} \propto p^{-n/2} \quad ,$$

   where $L_p \propto p^{1/2}$ is the p-adic length scale. By p-adic length scale hypothesis the p-adic prime p satisfies $p \simeq 2^k$. n is an exponent which need not be an integer.

   (b) Second suggestive possibility is logarithmic dependence on L_p and therefore on p.

Superluminal neutrinos cannot be tachyons

New Scientist (see `http://tinyurl.com/6qtjgny`) reported about the sad fate of the tachyonic explanation of neutrino super-luminality. The argument is extremely simple.

1. One can start by assuming that a tachyon having negative mass squared: $m(\nu)^2 < 0$ and assume that super-luminal velocity is in question. The point is that one knows the value of the superluminal velocity $v(1+\epsilon)c$, $\epsilon \simeq 10^{-5}$. One can calculate the energy of the neutrino as

   $$E = |m(\nu)|[-1 + v^2/(v^2-1)]^{1/2} \quad ,$$

   $|m(\nu)| = (-m(\nu)^2)^{1/2}$ is the absolute value of formally imaginary neutrino mass.

2. In good approximation one can write

   $$E = |m(\nu)|[-1 + (2\epsilon^{-1/2})]^{1/2} \simeq |m(\nu)|(2\epsilon)^{-1/2} \quad .$$

   The order of magnitude of $|m(\nu)|$ is not far from one eV - this irrespective of whether neutrino is tachyonic or not. Therefore the energy of neutrino is very small: not larger than keV. This is in a grave contradiction with what is known: the energy is measured using GeV as a natural unit so that there is discrepancy of 6 orders of magnitude at least. One can also apply energy conservation to the decay of pion to muon and neutrino and this implies that muon has gigantic energy: another contradiction.

What is amusing that this simple kinematic fact was not noticed from beginning. In any case, this finding kills all tachyonic models of neutrino super-luminality assuming energy conservation, and gives additional support for the TGD based explanation in terms of maximal signal velocity, which depends on pair of points of space-time sheet connected by signal and space-time sheet itself characterizing also particular kind of particle.

Even better, one can understand also the jitter (see `http://tinyurl.com/3h44vxw`) [C9] in the spectrum of the arrival times which has width of about 50 ns in terms of an effect caused fluctuations in gravitational fields to the maximal signal velocity expressible in terms of the induced metric [K7]. The jitter could have interpretation in terms of gravitational waves inducing fluctuation of the maximal signal velocity $c_\#$, which in static approximation equals to $c_\# = c(1+\Phi_{gr})^{1/2}$, where Φ_{gr} is gravitational potential.

Surprisingly, effectively super-luminal neutrinos would make possible

gravitational wave detector [K7]! The gravitational waves would be however gravitational waves in TGD sense having fractal structure since they would correspond to bursts of gravitons resulting from the decays of large $\hbar$ gravitons emitted primarily rather than to a continuous flow [K6]. The ordinary detection criteria very probably exclude this kind of bursts as noise. The measurements of Witte (see `http://tinyurl.com/yb98uhvd`) [E28] attempting to detect absolute motion indeed observed this kind of motion identifiable as a motion of Earth with respect to the rest frame of galaxy but superposed with fractal fluctuations proposed to have interpretation in terms of gravitational turbulence - gravitational waves.

4.1.3 Icarus refutes Opera result

Icarus collaboration (see http://tinyurl.com/y7eqcsma) [C8] has replicated the measurement of the neutrino velocity. The abstract summarizes the outcome.

The CERN-SPS accelerator has been briefly operated in a new, lower intensity neutrino mode with about 10^{12} *p.o.t. /pulse and with a beam structure made of four LHC-like extractions, each with a narrow width of about 3 ns, separated by 524 ns. This very tightly bunched beam structure represents a substantial progress with respect to the ordinary operation of the CNGS beam, since it allows a very accurate time-of-flight measurement of neutrinos from CERN to LNGS on an event-to-event basis. The ICARUS T600 detector has collected 7 beam-associated events, consistent with the CNGS delivered neutrino flux of* 2.2×10^{16} *p.o.t. and in agreement with the well known characteristics of neutrino events in the LAr-TPC. The time of flight difference between the speed of light and the arriving neutrino LAr-TPC events has been analyzed. The result is compatible with the simultaneous arrival of all events with equal speed, the one of light. This is in a striking difference with the reported result of OPERA that claimed that high energy neutrinos from CERN should arrive at LNGS about 60 ns earlier than expected from luminal speed.*

As explained, Tthe TGD based explanation for the anomaly would not have been superluminality but the dependence of the maximal signal velocity on space-time sheet: the geodesics in induced metric are not geodesics of the 8-D embedding space. In principle the time taken to move from A (say CERN) to point B (say Gran Sasso) depends on space-time sheets involved. One of these space-time sheets would be that assignable to particle beam - a good guess is "massless extremal" [K3]: along this the velocity is in in the simplest case (cylindrical "massless extremals") the maximal signal velocity in $M^4 \times CP_2$.

Other space-space-time sheets involved can be assigned to various systems such as Earth, Sun, Galaxy and they contribute to the effect. It is important to understand how the physics of test particle depends on the presence of parallel space-times sheets. Simultaneous topological condensation to all the sheets is extremely probable so that at classical level forces are summed. Same happens at quantum level. The superposition of various fields assignable to parallel space-time sheets is not possible in TGD framework and is replaced with the superposition of their effects. This allows to resolve one of the strongest objections against the notion induced gauge field.

The outcome of ICARUS experiment is not able to kill this prediction since at this moment I am not able to fix the magnitude of the effect. It is really a pity that such a fantastic possibility to wake up the sleeping colleagues is lost. I feel like a parent in a nightmare seeing his child to drown and being unable to do anything.

There are other well-established effects in which the dependence of maximal signal velocity on space-time sheet is visible: one such effect is the observed slow increase of the time spend by light ray to propagate moon and back. The explanation (see http://tinyurl.com/yawof8yt) [K7] is that the effect is not real but due to the change of the unit for velocity defined by the light-velocity assignable to the distant stars. The maximal signal velocity is for Robertson-Walker cosmology gradually increasing and the anomaly emerges as an apparent anomaly when one assumes that the natural coordinate system assignable to the solar system (Minkowski coordinates) is the natural coordinate system in cosmological scales. The size of the effect is predicted correctly. Since the cosmic signal velocity defining the unit increases, the local maximal signal velocity which is constant seems to be reducing and the measured distance to the Moon seems to be increasing.

4.2 SN1987A And Many-Sheeted Space-Time

Lubos Motl has written a highly rhetoric, polemic, and adrenaline rich posting (see http://tinyurl.com/px4hzdc) about the media buzz related to supernova SN1987A. The target of Lubos Motl is the explanation proposed by James Franson from the University of Maryland for the findings discussed in Physics Archive Blog (see http://tinyurl.com/mde7jat). I do not have any strong attitude to Franson's explanation but the buzz is about very real thing: unfortunately Lubos Motl tends to forget the facts in his extreme orthodoxy.

What happened was following. Two separate neutrino bursts arrived from SN 1987 A. At 7.35 AM Kamionakande detected 11 antineutrons, IMB 8 antineutrinos, and Baksan 5 antineutrinos. Approximately 3 hours later Mont Blanc liquid scintillator detected 5 antineutrinos. Optical signal came 4.7 hours later.

The are several very real problems as one can get convinced by going to Wikipedia (http://tinyurl.com/mglkm4):

1. If neutrinos and photons are emitted simultaneously and propagate with the same speed, they should arrive simultaneously. I am not specialist enough to try to explain this difference in terms of standard astrophysics. Franson however sees this difference as something not easy to explain and tries to explain it in his own model.

2. There are two neutrino bursts rather than one. A modification of the model of supernova explosion allowing two bursts of neutrinos would be needed but this would suggest also two photon bursts.

These problems have been put under the carpet. Those who are labelled as crackpots often are much more aware about real problems than the academic career builders.

In TGD framework the explanation would be in terms of many-sheeted space-time. In GRT limit of TGD the sheets of the many-sheeted space-time (see **Fig.** http://tgdtheory.fi/appfigures/manysheeted.jpg or **Fig. ??** in the appendix of this book) are lumped to single sheet: Minkowski space with effective metric defined by the sum of Minkowski metric and deviations of the metrics of the various sheets from Minkowski metric. The same recipe gives effective gauge potentials in terms of induced gauge potentials.

Different arrival times for neutrinos and photons would be however a direct signature of the many-sheeted space-time since the propagation velocity along space-time sheets depends on the induced metric. The larger the deviation from the flat metric is, the slower the propagation velocity and thus longer the arrival time is. Two neutrino bursts would have explanation as arrivals along two different space-time sheets. Different velocity for photons and neutrinos could be explained if they arrive along different space-time sheets. I proposed for more than two decades ago this mechanism as an explanation for the finding of cosmologists that there are two different Hubble constants: they would correspond to different space-time sheets.

The distance of SN1987A is 168, 000 light- years. This means that the difference between velocities is $\Delta c/c \simeq \Delta T/T \simeq 3hours/168 \times 10^3 \simeq 2 \times 10^{-9}$. The long distance is what makes the effect visible.

I proposed earlier sub-manifold gravity as an explanation for the claimed super-luminality of the neutrinos coming to Gran Sasso from CERN. In this case the effect would have been $\Delta c/c \simeq 2.5 \times 10^{-5}$ and thus four orders of magnitude larger than four supernova neutrinos. It however turned out that the effect was not real.

Towards the end of 2014 Lubos Motl Motl had a posting about galactic blackhole Sagittarius A as neutrino factory (see http://tinyurl.com/pvzrqoz). Chandra X-ray observatory (see http://tinyurl.com/6jdp7es) and also Nustar (http://tinyurl.com/89b8r96) and Swift Gamma-Ray Burst Mission (see http://tinyurl.com/ybmrpuu6) detected some X-ray flares from Sagittarius A. 2-3 hours earlier IceCube (see http://tinyurl.com/lg7mko) detected high energy neutrinos by IceCube on the South Pole.

Could neutrinos arrive from the galactic center? If they move with the same (actually somewhat lower) velocity than photons, this cannot be the case. The neutrinos did the same trick as SN1987A neutrinos and arrived 2-3 hours before the X-rays! What if one takes TGD seriously and estimates $\Delta c/c$ for this event? The result is $\Delta c/c \sim (1.25 - 1.40) \times 10^{-8}$ for 3 hours lapse using the estimate $r = 25,900 \pm 1,400$ light years (see http://tinyurl.com/5vexvq). $\Delta c/c$ is by a factor 4 larger than for SN1987A at distance about 168, 000 light years (see http://tinyurl.com/mglkm4). This distance is roughly 8 times longer. This would suggests that the smaller the space-time sheets the nearer the velocity of neutrinos is to its maximal value. For photons the reduction from the maximal signal velocity is larger.

4.3 Anomalous Time Dilation Effects Due To Warping As Basic Distinction Between TGD And GRT

TGD predicts the possibility of large anomalous time dilation effects due to the warping of space-time surfaces, and the experimental findings of Russian physicist Chernobrov about anomalous changes in the rate of flow of time [J2, J1] provide indirect support for this prediction.

4.3.1 Anomalous time dilation effect due to the warping

Consider first the ordinary gravitational time dilation predicted by GRT. For simplicity consider a stationary spherically symmetric metric $ds^2 = g_{tt}dt^2 - g_{rr}dr^2 - r^2 d\Omega^2$ in spherical coordinates. The time dilation is characterized by the difference $\Delta = \sqrt{g_{tt}} - 1$. In the weak field approximation one has $g_{tt} = 1 + 2\Phi_{gr}$, where Φ_{gr} is gravitational potential. The ordinary time dilation is given by $\Delta = \sqrt{g_{tt}} - 1 \simeq 2\Phi_{gr}$. At the Earth's surface the gravitational potential of the Earth is about $\Phi_{gr} = GM/R_E \simeq 10^{-9}$.

Consider next the situation for space-time surfaces. There exists an infinite number of warped embeddings of M^4 to $M^4 \times CP_2$ given by $s^k = s^k(m^0)$, which are metrically equivalent with the canonical embedding with CP_2 coordinates constant. New M^4 time coordinate is related by a diffeomorphism to the standard one. By restricting the embedding to $M^4 \times S^1$, where S^1 a geodesic circle with radius $R/2$ (using the chosen convention for the definition CP_2 radius), the time component of the induced metric is $g_{m^0m^0} = 1 - R^2\omega^2/4$. The identification of M^4 coordinates as the preferred natural standard coordinate frame allows to overcome the difficulties related to the identification of the preferred time coordinate in general relativity in the case the metric does not approach asymptotically flat metric. For this choice an anomalous time dilation $\sqrt{1 - R^2\omega^2/4}$ due to the warping results even when gravitational fields are absent. Moreover, the dilation can be large.

The study of the embeddings of Scwhartshild metric as vacuum extremals demonstrates that this vacuum warping is also seen as the degeneracy of the embeddings of stationary spherically symmetric metrics. If m^0 is used as a time coordinate, anomalous time dilation is obtained also at $r_M \to \infty$ and is given by

$$\sqrt{g_{m^0m^0}} = \frac{1}{\lambda} . \quad (4.1)$$

This time dilation is seen only if the clocks to be compared are at different space-time sheets. The anomalous time dilation can be quite large since the order of magnitude for the parameter ωR is naturally of order one for the embeddings of R-N metrics.

4.3.2 Mechanisms producing anomalous time dilation

Anomalous time dilation could result in many ways.

1. An adiabatic variation of the parameters λ and ω_1 of the space-time sheet containing the clock could be induced by some physical mechanism. For instance, X^4_c could move "over" a large space-time sheet X^4 and gradually form $\#$ and $\#_B$ contacts with it. Topological light rays (MEs) define a good candidate for X^4. The parameter values λ and ω could change quasi-continuously if X^4_c gradually generates CP_2 sized wormhole contacts or flux tubes connecting it to X^4. This process would not affect the gravitational flux fed to X^4_c.

   For instance, if X^4 is at rest with respect to Earth, this motion would result from the rotation of Earth and the effect should appear periodically from day to day. If it is at rest with respect to Sun, the effect should appear once a year.

   The generation of vacuum extremals X^4_{vac} (not gravitational vacua), which is in principle possible even by intentional action since conservation laws are not broken, could induce anomalous time dilation by this mechanism.

2. A phase transition increasing the value of $\hbar$ increases the size of the space-time sheet in the same proportion. This transition could quite well affect also the parameter λ. If this phase transition occurs for the space-time sheet X^4_c at which the clock feeds its gravitational flux, this mechanism could provide a feasible manner to induce an anomalous time dilation.

3. The system containing the clock could suffer a temporary topological condensation to a smaller space-time sheet and thus feed its gravitational flux to this space-time sheet. This would require coherently occurring splitting of $\#$ contacts and their regeneration. It is not possible to say anything definite about the probability of this kind of process except that it does not look very feasible.

4.3.3 The findings of Chernobrov

The findings claimed by Russian researcher V. Chernobrov support anomalous time dilation effect [J2, J1]. Chernobrov has studied anomalies in the rate of time flow defined operationally by comparing the readings of clocks enclosed inside a spherical volume with the readings of clocks outside this volume. The experimental apparatus involves a complex Russian doll like structure of electromagnets.

Chernobrov reports a slowing down of time by about 30 seconds per hour inside his experimental apparatus [J2] so that the average dilation factor during hour would be about $\Delta = 1/120$. If the dilation is present all the time, the anomalous contribution to the gravitational potential would be by a factor $\sim 10^7$ larger than that of Earth's gravitational potential and huge gravitational perturbations would be required to produce this kind of effect.

The slowing of the time flow is reported to occur gradually whereas the increase for the rate of time flow is reported to occur discontinuously. Time dilation effects were observed in connection with the cycles of moon, diurnal fluctuations, and even the presence of operator.

Consider now the explanation of the basic qualitative findings of Chernobrov.

1. The gradual slowing of the time flow suggests that the parameter values of λ and ω change adiabatically. This favors option 1) since the formation of # contacts occurs with some finite rate.

2. Also the sudden increase of the rate of time flow is consistent with option 1) since the splitting of # contacts occurs immediately when the sheets X^4_c and X^4 are not "over" each other.

3. The occurrence of the effect in connection with the cycles of moon, diurnal fluctuations, and in the presence of operator support this interpretation. The last observation would support the view that intentional generation of almost vacuum space-time sheets is indeed possible.

4.3.4 Vacuum extremals as means of generating time dilation effects intentionally?

Field equations allow a gigantic family of vacuum extremals: any 4-surface having CP_2 projection, which belongs to a 2-dimensional Lagrange manifold with a vanishing induced Kähler form, is a vacuum extremal. Symplectic transformations and diffeomorphisms of CP_2 produce new vacuum extremals. Vacuum extremals carry non-vanishing classical electro-weak and color fields which are reduced to some $U(1)$ subgroup of the full gauge group and also classical gravitational field. Although the vacuum extremals are not absolute minima, their small deformations could define such. These vacuum extremals, call them X^4_{vac} for brevity, could be generated by intentional action. In the first quantum jump the p-adic variant of the vacuum extremal representing an intention to create X^4_{vac} would appear and in some subsequent quantum jump it would be transformed to a real space-time sheet.

The creation of these almost vacuum extremals could generate time dilation effects. The material system would gradually generate CP_2 sized wormhole contacts and/or flux tubes connecting its space-time sheet to X^4_{vac} and this could change the values of the vacuum parameters λ, ω.

4.3.5 Could warping have something to do with condensed matter physics?

Warping predicts the reduction of the effective light velocity. There is a report [D2] of an experimental study of a condensed-matter system (graphene, a single atomic layer of carbon, in which electron transport is essentially governed by massless Dirac's equation. According to the report, the charge carriers in graphene mimic relativistic particles with zero rest mass and have an effective "speed of light" $c_1 = c/300 = 10^6$ m/s.

The study reveals a variety of unusual phenomena that are characteristic of two-dimensional Dirac fermions. Graphene's conductivity never falls below a minimum value corresponding to the quantum unit of conductance, even when the concentrations of charge carriers tend to zero. The integer quantum Hall effect in graphene is anomalous in that it occurs at half-integer filling factors. The cyclotron mass m_c of massless current carriers in graphene is defined in terms of the energy of current carrier as $E = m_c c_1^2$.

The authors believe that these phenomena can be understood in the framework of the ordinary QED and this might be the case. One can however wonder whether the massless Dirac equation for the 2-dimensional system could correspond to the Kähler-Dirac equation for the induced spinor fields and whether the reduction of the maximal signal velocity to c_1 could have the warping of the space-time sheet as a space-time correlate. In the idealization that the CP_2 projection of the space-time surface is a geodesic circle of CP_2, and using M^4 coordinates for space-time surface, so that one would have $\Phi = \omega t$ for S^2 coordinate Φ, one would have $g_{tt} = c_1^2 = 1 - R^2\omega^2/4 = 10^{-4}/9$.

4.4 Evidence For Many-Sheeted Space-Time From Gamma Ray Flares

MAGIC collaboration has found evidence for a gamma ray anomaly. Gamma rays in different energy ranges seem to arrive with different velocities from Mkn 501 [E13]. The delay in arrival times is about 4 minutes. The proposed explanation is in terms of broken Lorentz invariance. TGD allows to explain the finding in terms of many-sheeted space-time and there is no need to invoke breaking of Lorentz invariance.

4.4.1 TGD based explanation at qualitative level

One of the oldest predictions of many-sheeted space-time is that the time for photons to propagate from point A to B along given space-time sheet depends on space-time sheet because photon travels along light-like geodesic of space-time sheet rather than light-like geodesic of the embedding space and thus increases so that the travel time is in general longer than using maximal signal velocity.

Many-sheetedness predicts a spectrum of Hubble constants and gamma ray anomaly might be a demonstration for the many-sheetedness. The spectroscopy of arrival times would give information about how many sheets are involved.

Before one can accept this explanation, one must have a good argument for why the space-time sheet along which gamma rays travel depends on their energy and why higher energy gamma rays would move along space-time sheet along which the distance is longer.

1. Shorter wavelength means that the wave oscillates faster. Space-time sheet should reflect in its geometry the the matter present at it. Could this mean that the space-time sheet is more "wiggly" for higher energy gamma rays and therefore the distance traveled longer? A natural TGD inspired guess is that the p-adic length scales assignable to gamma ray energy defines the p-adic length scale assignable to the space-time sheet of gamma ray connecting two systems so that effective velocities of propagation would correspond to p-adic length scales coming as half octaves. Note that there is no breaking of Lorentz invariance since gamma ray connects the two system and the rest system of receiver defines a unique coordinate system in which the energy of gamma ray has Lorentz invariant physical meaning.

2. One can invent also an objection. In TGD classical radiation field decomposes into topological light rays ("massless extremals", MEs) which could quite well be characterized by a large Planck constant in which case the decay to ordinary photons would take place at the receiving end via de-coherence. Gamma rays could propagate very much like a laser beam along the ME. For the simplest MEs the velocity of propagation corresponds to the maximal signal velocity and there would be no variation of propagation time.

   One can imagine two ways to circumvent to the counter argument.

   i) Also topological light rays for which light-like geodesics are replaced with light-like curves of M^4 are highly suggestive as solutions of field equations. For these MEs the distance travelled would be in general longer than for the simplest MEs.

   ii) The gluing of ME to background space-time by wormhole contacts (actually representation for photons!) could force the classical signal to propagate along a zigzag curve formed by simple MEs with maximal signal velocity. The length of each piece would be of order p-adic length scale. The zigzag character of the path of arrival would increase the distance between source and receiver.

4.4.2 Quantitative argument

A quantitative estimate runs as follows.

1. The source in question is quasar Makarian 501 with redshift $z = .034$. Gamma flares of duration about 2 minutes were observed with energies in bands.25-.6 TeV and 1.2-10 TeV. The gamma rays in the higher energy band were near to its upper end and were delayed by about $\Delta\tau = 4$ min with respect to those in the lower band. Using Hubble law $v = Hct$ with $H = 71$ km/Mparsec/s, one obtains the estimate $\Delta\tau/\tau = 1.6 \times 10^{-14}$.

2. A simple model for the induced metric of the space-time sheet along which gamma rays propagate is as a flat metric associated with the flat embedding $\Phi = \omega t$, where Φ is the angle coordinate of the geodesic circle of CP_2. The time component of the metric is given by

$$g_{tt} = 1 - R^2\omega^2 \quad .$$

ω appears as a parameter in the model. Also the embeddings of Reissner-Norström and Schwartschild metrics contain frequency as free parameter and space-time sheets are quite generally parameterized by frequencies and momentum or angular momentum like vacuum quantum numbers.

3. ω is assumed to be expressible in terms of the p-adic prime characterizing the space-time sheet. The parameterization to assumed in the following is

$$\omega^2 R^2 = Kp^{-r} \quad .$$

It turns out that $r = 1/2$ is the only option consistent with the p-adic length scale hypothesis. The naïve expectation would have been $r = 1$. The result suggests the formula

$$\omega^2 = m_0 m_p \ \text{ with } \ m_0 = \frac{K}{R} \quad .$$

ω would be the geometric mean of a slowing varying large p-adic mass scale and p-adic mass scale m_p.

The explanation for the p-adic length scale hypothesis leading also to a generalization of Hawking-Bekenstein formula assumes that for the strong form of p-adic length scale hypothesis stating $p \simeq 2^k$, k prime, there are two p-adic length scales involved with given elementary particle. L_p characterizes particle's Compton length and L_k characterizes the size of the wormhole contact or throat representing the elementary particle. The guess is that ω is proportional to the geometric mean of these two p-adic length scales:

$$\omega^2 R^2 = \frac{x}{2^{k/2}\sqrt{k}} \quad .$$

4. A relatively weak form of the p-adic length scale hypothesis would be $p \simeq 2^k$, k an odd integer. M_{127} corresponds to the mass scale $m_e 5^{-1/2}$ in a reasonable approximation. Using $m_e \simeq .5$ MeV one finds that the mass scales $m(k)$ for $k = 89 - 2n$, $n = 0, 1, 2..., 6$ are $m(k)/TeV = x$, with $x = 0.12, 0.23, 0.47, 0.94, 1.88, 3.76, 7.50$. The lower energy range contains the scales $k = 87$ and 85. The higher energy range contains the scales $k = 83, 81, 79, 77$. In this case the proposed formula does not make sense.

5. The strong form of p-adic length scale hypothesis allows only prime values for k. This would allow Mersenne prime M_{89} (intermediate gauge boson mass scale) for the lower energy range and $k = 83$ and $k = 79$ for the upper energy range. A rough estimate is obtained by assuming that the two energy ranges correspond to $k_1 = 89$ and $k_2 = 79$.

6. The expression for τ reads as $\tau = (g_{tt})^{1/2}t$. $\Delta\tau/\tau$ is given by

$$\begin{aligned} \frac{\Delta\tau}{\tau} &\simeq (g_{tt})^{-1/2}\frac{\Delta g_{tt}}{2} \simeq R^2\Delta\omega^2 = x[(k_2p_2)^{-1/2} - (k_1p_1)^{-1/2}] \simeq x(k_2p_2)^{-1/2} \\ &= x2^{-79/2}79^{-1/2} \quad . \end{aligned}$$

Using the experimental value for $\Delta\tau/\tau$ one obtains $x \simeq .45$. $x = 1/2$ is an attractive guess.

4.5 Do Ultracold Neutrons Provide Direct Evidence For Many-Sheeted Space-Time?

There was a very interesting article about magnetic anomaly UCN trapping (see http://tinyurl.com/y8z6kff5) . UCN is a shorthand for ultra-cold neutrons. The article [C5] had a somewhat provocative title *Magnetic anomaly in UCN trapping: signal for neutrons oscillations to parallel world?*. Perhaps this was explains why I did not bother to look at it at the first time I saw it.

As I saw again the popular story hyping the article, I realized that the anomaly - if real - could provide a direct evidence for the transitions of neutrons between parallel space-time sheets of many-sheeted space-time. TGD of course predicts that this phenomenon is completely general applying to all kinds of particles.

The interpretation of authors is that ultra-cold neutrons oscillate between parallel worlds- albeit in different sense as in TGD. The authors describe this oscillation using same mathematical model as describing neutrino oscillations. What would be observed would be that in statistical sense neutrons in the beam disappear and reappear periodically. The model predicts that the frequency for this is just the Larmor frequency $\omega = \mu \cdot B/2$ for the precession of spin of neutron in magnetic field. The authors claim that just this is observed and the interpretation is somewhat outlandish looking. Standard model gauge group is doubled: all particles have exact mirror copies with same quantum numbers. This of course is extremely inelegant interpretation. Something much more elegant is needed.

4.5.1 TGD based description of the situation

TGD allows to understand the finding in terms of many-sheeted space-time and one ends up with a phenomenological model similar to that of authors. Now however the phenomenon is predicted to be completely general applying to all kinds of particles and does not require the weird doubling of standard model symmetries.

Imagine the presence of two space-time sheets (or even more of them) carrying magnetic fields which decompose to flux tubes.

1. Suppose that neutron is topologically condensed in one of these flux tubes. What happens when the flux tubes are "above each other" in the sense that their Minkowski space projections intersect and the flux tubes are extremely near to each other: the distance is of order CP_2 size of order 10^4 Planck lengths. It took long time to take seriously the obvious: neutrons topologically condense on both space-time sheets and experience the sum of the magnetic fields in these regions. This actually allows to overcome the basic objection against TGD due to the fact that all classical gauge fields are expressible in terms of CP_2 coordinates and their gradients so that enormously powerful constraints between classical gauge fields are satisfied and linear superposition of fields is lost. In many-sheeted space-time this superposition is replaced with the superposition of their effects in multiple topological condensation,

2. In the regions where the intersection of M^4 projections of flux tubes is empty, topological condensation takes place on either space-time sheet.

3. What happens when one has neutrons propagating along flux tube 1 characterized by magnetic field B_1 arrive to a region where flux tube 2 of magnetic field B_2 resides? In the intersection region the neutrons experience the field $B_1 + B_2$ in good approximation. The interaction energy $E = \mu B \cdot \sigma$, where B is the magnetic field and σ is the spin of neutron. In flux tube 1 has $B = B_1$, in flux tube 2 one has $B = B_2$ and in the intersection region $B = B_1 + B_2$. It can happen that neutron arriving along flux tube 1 continues its travel along flux tube 2.

4. Magnetic fields in question actually consists of large number of nearly parallel flux tubes and the travel of neutron is a series of segments: $B_{i_1} \to B_1 + B_2 \to B_{i_2} \to$ ..... As if neutron would make jumps between parallel worlds. Now these worlds are geometrically parallel rather than identifiable as copies in tensor product of standard model gauge groups.

A phenological description predicting the probabilities for the transitions between the parallel worlds assignable to the two magnetic fields could be based on simple Hamiltonian used to describe also neutrino mixing. Hamiltonian is sum of spin Hamiltonians $H_i = \mu B_i \cdot \sigma$ and of non-diagonal mixing term ϵ. $H = H_1 \oplus H_2 + \epsilon$. The diagonal term H_i are non-vanishing in the nonintersecting region i and non-diagonal describing what happens in the intersecting regions. Just this description was used by the authors of the article to parametrize the observed anomaly.

One can test this interpretation by introducing a third magnetic field. The interpretation of authors might force to introduce even third copy of standard model gauge group.

4.5.2 Amusing co-incidence

What is so amusing that the magnetic field used in the experiments was .2 Gauss. It is exactly the nominal value of the endogenous magnetic field needed to explain the strange quantal effects of radiation at cyclotron frequencies of biologically important ions on vertebrate brain. The frequencies are extremely low - in EEG range - and corresponding thermal energies are 10 orders below thermal energy so that standard quantum mechanics predicts no effects. The explanation assumes $B_{end} = .2$ GeV containing dark variants of these ions with so large Planck constants that the cyclotron energies are above thermal energy at physiological temperatures.

Why experimentalists happened to use just this.2 Gauss magnetic field which is 2/5 of the nominal value of the Earth's magnetic field $B_E = .5$ Gauss? If I were a paranoid, I would swear that the experimentalists were well aware of TGD. Of course they were not! One cannot be aware of TGD in a company of respectable scientists and even less in respectable science journals!

4.6 Is Gravitational Constant Really Constant?

The most convincing TGD based model for the p-adic coupling constant evolution identified hitherto [K11] predicts that gravitational coupling constant is proportional to the square of p-adic length scale: $G \propto L_p^2$. Together with p-adic length scale hypothesis this would predict that gravitational coupling strength can have values differing from its standard value by a power of 2. $p = M_{127}$ would characterize the space-time sheet mediating ordinary gravitational interactions. In the following possible indications for the variation of G is discussed.

4.6.1 The case of Bullet cluster

The studies of the Bullet cluster [E15, E11], provide the best evidence to date for the existence of dark matter. Bullet cluster [E3] consists of two colliding clusters of galaxies (strictly speaking, the term refers to the smaller one of the two clusters). The major components of the cluster pair, stars, gas and the putative dark matter, behave differently during collision, allowing them to be studied separately.

The stars of the galaxies, observable in visible light, were not greatly affected by the collision, and most passed right through, gravitationally slowed but not otherwise altered. The hot gas of the two colliding components, seen in X-rays, represents about 90 per cent of the mass of the ordinary matter in the cluster pair. The gases interact electromagnetically, so that the velocity change for the gases of clusters is larger than for the stars of clusters. The dominating dark matter component was detected indirectly by its gravitational lensing. The observation that the lensing is strongest in two separated regions near the visible galaxies, confirms with the assumption that most of the mass in the cluster pair is in the form of collisionless dark matter.

Particularly compelling results were inferred from the Chandra observations of the bullet cluster. Those authors report that the cluster is undergoing a high-velocity [around 4500 km/s] merger, evident from the spatial distribution of the hot, X-ray emitting gas, but this gas lags behind the sub-cluster galaxies. Furthermore, the dark matter clump, revealed by the weak-lensing map, is coincident with the collisionless galaxies, but lies ahead of the collisional gas.

Later came the work of Glennys Farrar, Rachel Rosen, and Volker Springler [E29] suggesting that the situation might not be as simple as this (for a popular article see [E31]). The velocity of the bullet of dark matter is higher than it should be in the cold dark matter scenario (CDM). The proposal is that dark matter has its own additional attractive interaction of finite range, "fifth force". Since the finite range of the force is not actually significant in the situation considered, the model is mathematically equivalent with a model assuming that dark gravitational coupling strength. A good fit is obtained by assuming that the net effective gravitational force is by a factor 2 stronger than gravitational force.

The hypothesis is claimed to solve also some other problems of the cold dark matter scenario (CDM). The number of dwarf galaxies around ordinary galaxies is considerably smaller than predicted by CDM. The strong binding of dark matter in dwarfs would make them more compact and this in turn would mean that the binding of visible matter is weaker so that ordinary galaxies would have ripped this matter off and dwarfs would be more difficult to detect. CDM also predicts less galaxy clusters and stronger attraction for dark matter could resolve the problem.

TGD strongly suggests that gravitational constant is proportional to the square of p-adic length scale: $G \propto L_p^2 \equiv L(k)^2$, $p \simeq 2^k$, k integer, in particular power of prime. Ordinary gravitational constant would correspond to $p = M_{127} = 2^{127} - 1$, which is the largest Mersenne prime which is not completely super-astrophysical and corresponds to electron's p-adic length scale. One can however ask whether it might be possible to have situations in which the p-adic length scale assigned to the space-time sheets mediating gravitational interaction differs from M_{127}. $L(k)$ $k = 2^7 = 128$, would would correspond to $G \rightarrow 2G$. The growth of the gravitational coupling strength could be a transient phenomenon taking place only during the collision.

4.6.2 Shrinking kilogram

The definition of kilogram [E8] is not the topics number one in coffee table discussions and definitely not so because it could lead to heated debates. The fact however is that even the behavior of standard kilogram can open up fascinating questions about the structure of space-time.

The 118-year old International Prototype Kilogram is an alloy with 90 per cent Platinum and 10 per cent Iridium by weight (gravitational mass). It is held in an environmentally monitored vault in the basement of the BIPMs House of Breteuil in Sevres on the outskirts of Paris. It has forty copies located around the world which are compared with Sevres copy with a period of 40 years.

The problem is that the Sevres kilogram seems to behave in a way totally in-appropriate taking into account its high age if the behavior of its equal age copies around the world is taken as the norm [C10], [E8]. The unavoidable conclusion from the comparisons is that the weight (gravitational mass) of Sevres kilogram has been reduced by about 50 μg during 118 years which makes about

$$\frac{dlog(m)}{dt} = -4.2 \times 10^{-10}/year \ .$$

for Sevres copy or relative increase of same amount for its copies.

Specialists have not been able to identify any convincing explanation for the strange phenomenon. For instance, there is condensation of matter from the air in the vault which increases the weight and there is periodic cleaning procedure which however should not cause the effect.

1. *Could the non-conservation of gravitational energy explain the mystery?*

The natural question is whether there could be some new physics mechanism involved. If the copies were much younger than the Sevres copy, one could consider the possibility that gravitational mass of all copies is gradually reduced. This is not the case. One can still however look what this could mean.

Equivalence Principle (EP) holds in classical sense for the GRT limit of TGD understood as effective theory with effective space-time in long length scales defined as M^4 endowed with an effective metric defined as the sum of Minkowski metric and sum of deviations from Minkowski metric for various space-time sheets involved. Thus GRT space-time lumps together the space-time sheets of many-sheeted space-time and there is always a length scale resolution involved. EP reduces to Einstein's equations and reflects underlying Poincare invariance.

In Zero Energy Ontology (ZEO) zero energy states and corresponding space-time surfaces reside always inside some causal diamond (CD) characterized by scale. Therefore the conserved four-momentum assignable to either end of CD is scale dependent quantity, and the apparent non-conservation of four-momentum as scale is changed is not in conflict with Poincare invariance.

At the quantum level EP would hold true in the sense that classical Noether charges in the Cartan algebra of isometries and associated with Kähler action are equal to the eigenvalues of the quantal charges of Kähler-Dirac action: EP would reduce to Quantum classical correspondence. Holography allows to consider also the possibility that gravitational and inertial charges correspond to those assignable to light-like and space-like 3-surfaces respectively.

One cannot expected Einstein's equations and EP for *single space-time sheet* endowed with the induced metric. For the embeddings of metrics (not necessary extremals of Kähler action) for which it is possible to define gravitational energy gravitational energy need not be non-conserved. This occurs even in the case of stationary metrics such as Reissner-Nordström exterior metric and the metrics associated with stationary spherically symmetric star models imbedded as vacuum extremals as has been found.

The basic reason is that Schwartschild time t relates by a scaling and shift to Minkowski time m^0:

$$m^0 = \lambda t + h(r)$$

such that the shift depends on the distance r to the origin. The Minkowski shape of the 3-volume containing the gravitational energy changes with M^4 time but this does not explain the effect. The key observation is that the vacuum extremal of Kähler action is not an extremal of the curvature scalar (these correspond to asymptotic situations). What looks first really paradoxical is that one obtains a constant value of energy inside a fixed constant volume but a non-vanishing flow of energy to the volume. The explanation is that the system simply destroys the gravitational energy flowing inside it! The increase of gravitational binding energy compensating for the feed of gravitational energy gives a more familiar looking articulation for the non-conservation.

Amusingly, the predicted rate for the destruction of the inflowing gravitational energy is of same order of magnitude as in the case of kilogram. Note also that the relative rate is of order $1/a$, a the value of cosmic time of about 10^{10} years. The spherically symmetric star model also predicts a rate of same order.

This approach of course does not allow to understand the behavior of the kilogram since it predicts no change of gravitational mass inside volume and does not even apply in the recent situation since all kilograms are in same age. The co-incidence however suggests that the non-conservation of gravitational energy might be part of the mystery. The point is that if the inflow satisfies Equivalence Principle then the inertial mass of the system would slowly increase whereas gravitational mass measured far enough from gravitational acceleration caused by the *entire* system would remain constant: this would hold true only in steady state.

2. Minimal model assuming EP and many-sheeted space-time?

The minimal model assumes EP and many-sheeted space-time and its description based on GRT. In TGD Universe the increase of the inertial (and gravitational) mass could be due to the flow of matter from larger space-time sheets to the system, now the masses which are brought to Sevres for comparison.

The additional mass would not enter in via the surface of the kilogram but like a Trojan horse from the interior and it would be thus impossible to control using present day technology. The flow would continue until a flow equilibrium would be reached with as much mass leaving the kilogram as entering it.

What would distinguish between Sevres kilogram and its cousins? Could it be that the inertial mass of every kilogram increases gradually until a steady state is achieved? When the system is transferred to another place the saturation situation is changed to a situation in which genuine transfer of inertial and gravitational mass begins again and leads to a more massive steady state. The very process of transferring the comparison masses to Sevres would cause their increase.

As noticed, the in-flow of the gravitational mass per mass unit is of the same order of magnitude as that for the gravitational energy predicted by simple star models. Does this mean that the embedding of Schwartschild metric as vacuum extremal with effective metric identifiable as induced metric is a good approximation? If so then also single-sheetedness would be a good approximation. The hypothesis that GRT space-times correspond to vacuum extremals has indeed been a basic assumption in TGD based models of cosmology and astrophysics [K13, K8].

5 Could The Measurements Trying To Detect Absolute Motion Of Earth Allow To Test Sub-Manifold Gravity?

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 (see `http://tinyurl.com/ycxmc9lb`) [E5] 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 [C9] [K5].

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 embedding 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 [E26] 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 [E26], who has carried out a re-analysis of experiments trying to detect what he calls absolute motion using these formulas. Cahill has also replicated [E27] the crucial experiments of Witte [E28].

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 [C9].

5.1 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.

5.1.1 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:

$$\begin{aligned} V &\rightarrow V_1(v,u) \equiv \frac{V+vu}{1+\frac{Vv}{c_{\#}^2}u)} = \frac{V+vu}{V+\frac{v}{nc_{\#}}u)} \ , \\ V &= \frac{c_{\#}}{n} \ , \ u = cos(\theta) \ . \end{aligned} \tag{5.1}$$

   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.

5.1.2 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 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

$$r = \frac{\Delta T(v,\theta)}{T_0} \quad , \; , T_0 = \frac{2L}{V} = \frac{2Ln}{c_\#} \quad . \tag{5.2}$$

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:

$$\begin{aligned}
\Delta T &= T(v,\theta) - T(v,\theta+\pi/2) \ , \\
T(v,\theta) &= \frac{L}{V_1(v,u=cos(\theta))} + \frac{L}{V_1(v,-u=cos(\theta+\pi))} \ , \\
V_1(v,u) &= \frac{V+vu}{1+\frac{Vv}{c_\#^2}u} \ , \ u = cos(\theta) \ , \ V = \frac{c_\#}{n} \ .
\end{aligned} \tag{5.3}$$

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

$$\frac{\Delta T}{T_0} \simeq (n^2-1)\beta^2 cos(2\theta) = (n^2-1)(\frac{v}{c_\#})^2 cos(2\theta) \quad . \tag{5.4}$$

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 (see `http://tinyurl.com/y9cjp7js`) [E26]. 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

$$\frac{\Delta T}{T_0} \simeq 2\epsilon\beta^2 cos(2\theta) = 2\epsilon(\frac{v}{c_\#})^2 cos(2\theta) \quad . \tag{5.5}$$

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

$$\frac{\Delta T}{T_0} \simeq 2\beta^2 n^2 cos(2\theta) \ . \tag{5.6}$$

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

$$\begin{aligned} r &= \frac{\Delta T}{T_0} = \frac{T(v,\theta) - T_0}{T_0} \\ &= \frac{1 + \frac{\beta u}{n}}{1 + \beta u n} - 1 \simeq \beta(\frac{1-n^2}{n})u - \beta^2 u^2 \ , \\ n &= \frac{c_{\#}}{V} \ , \ u = cos(\theta) \ . \end{aligned} \tag{5.7}$$

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

$$\begin{aligned} r &\simeq -2\epsilon\beta u - \beta^2 u^2 \ , \\ n &= \frac{c_{\#}}{V} \ , \ u = cos(\theta) \ . \end{aligned} \tag{5.8}$$

   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

$$\begin{aligned} r &= \frac{\Delta T}{2T_0} = \frac{T(v,\theta) + T(v,\theta+\pi) - 2T_0}{2T_0} \simeq -\beta^2 u^2 (n^2 - 1) \simeq -2\epsilon\beta^2 u^2 \ , \\ u &= cos(\theta) \ . \end{aligned} \tag{5.9}$$

   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 (see http://tinyurl.com/y9cjp7js) 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.

5.1.3 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 [C9].

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 [C9].

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 [K5].

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!

5.2 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* (see `http://tinyurl.com/ydxhrakx`) [E24].

Ulianov proposed that one could perhaps understand neutrino super-luminality in terms of Witte effect (see `http://tinyurl.com/yb98uhvd`) [E28]. 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 [C9].

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* (see `http://tinyurl.com/y9cjp7js`) [E26]. 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)* (see `http://tinyurl.com/yb98uhvd`) [E28].

3. The article *A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected* (see `http://tinyurl.com/yb98uhvd`) [E27] 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.

5.2.1 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 (see `http://tinyurl.com/y3quue`) [E9] 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 (see `http://tinyurl.com/yb98uhvd`) [E28] that 7 interferometer experiments has been carried out during more than century.

Cahill has re-analyzed (see `http://tinyurl.com/y9cjp7js`) [E26] 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) (see `http://tinyurl.com/yb98uhvd`) [E28]. 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 (see `http://tinyurl.com/yb98uhvd`). Fluctuations in propagation time can be understood as being due to the fluctuations of $c_{\#}$.

2. Cahill re-analyzes (see `http://tinyurl.com/y9cjp7js`) [E26] 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 (see `http://tinyurl.com/476zk5g`) for the velocity as $(\alpha, \delta) = (5.2 \text{ hr}, 67^o)$. 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* (see `http://tinyurl.com/y6u9c4yp`) [E27] 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.

5.2.2 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 [E28] (see `http://tinyurl.com/yb98uhvd`). 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 (see http://tinyurl.com/9632q) 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 (see http://tinyurl.com/yb2pzu8p) [E27]. 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 ways 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.

5.3 Cahill's Work In Relation To TGD

Cahill has also introduced a theoretical framework to explain the findings of De Witte and re-interpreted 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 (see `http://tinyurl.com/y9zvld5m`) [B2]. 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 Cahill's quantum foam inflow theory of gravity* (see `http://tinyurl.com/ya38rgf8`) [B1].

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 [K13] 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 [K6]. 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 precedessors 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.

6 Miscellaneous Topics

I have collected in this section miscellaneous topics for which I have not found any natural place in preceding sections. They are not necessarily about gravitational anomalies.

6.1 Michelson Morley Revisited

The famous Michelson-Morley experiment [E9] carried out for about century ago demonstrated that the velocity of light does not depend on the velocity of the source with respect to the receiver and killed the ether hypothesis. This could have led to the discovery of Special Relativity. Reality is not so logical however: actually Einstein ended up with his Special Relativity from the symmetries of Maxwell's equations. Amusingly, for hundred years later Sampo Pentikäinen told me about a Youtube video reporting a modern version of Michelson-Morley experiment by Martin Grusenick [E23] in which highly non-trivial results challenging the general relativistic view about the nearby gravitational fields of astrophysical objects are reported.

To my best knowledge there is no written document about the experiment of Martin Grusenick in web but the Youtube video [E23] is excellent. The reader willing to learn in more detail how Michelson-Morley interferometer works might find Youtube videos [E1] interesting. The result could be an artefact of the experimental arrangement, and it indeed turned out that the attempt of Frank Pierce to reproduce the effect one year later failed. Pierce also demonstrates in his video [E17] a possible reason for the artefact. I decided however to keep this section as it was since the attempt to explain this probably non-existing effect led to a considerable increase in the understanding of zero energy ontology.

6.1.1 Experimental arrangement and results

Grusenick's interferometer [E23] uses green light (532 nm wavelength) with 5 mW power from a laser powered by a battery. The light from the laser arrives at a beam splitter at angle of 45 degrees with respect to the beam direction and decomposes to two beams in directions orthogonal to each other. These beams are reflected back at mirrors having same distance from the splitter and combine again at beam splitter and travel to what to my best understanding should be a concave mirror magnifying and reflecting the interference pattern to a plywood screen. Also the longer video demonstrates that the mirror must be concave. Grusenick however talks about planar mirror but this cannot be the case if the mirror is orthogonal to the incoming beam as it seems to be (in the German version of the video he uses "einfach" instead of "planar" so that a linguistic lapsus or wrong pattern recognition on my side is probably in question). Video camera records the time development of the interference pattern as the arrangement mounted to a rotating tripod is rotated in plane. The plane is parallel to the Earth's surface in the first experiment and orthogonal to it in the second one.

When the rotation takes place in the plane parallel to the surface of Earth the interference pattern remains stationary during rotation. This is the result that Michelson obtained for 100 years ago. When the plane of rotation is orthogonal to the surface of Earth situation changes dramatically, and there is a clear shift of the interference pattern depending on the angle of rotation. The effect cannot be explained as being due to a motion of Earth with respect to ether since the direction of motion would be orthogonal to the Earth's surface at the measurement point and can be so only at certain measurement times since Earth rotates.

When the rotation plane is orthogonal to the surface of Earth one finds following.

1. The maximum shift of the interference pattern corresponds to 11-11.5 peaks which translates to a distance difference of 22-23 wavelengths from the beam splitter to the two orthogonal reflecting mirrors. The corresponding distance is $x = 11.70 - 12.23\ \mu$m. I do not know the precise distance between the beam splitter and mirror. If it equals to $l = .1$ meters, the difference in distance generated during the travel from the splitter to a mirror and back can be expressed as $x/l = x \times 10^{-5} \sim 10^{-4}$. From the point of view of the failing ether hypothesis this would mean $v/c \sim 10^{-4}$.

2. The shift for the interference pattern becomes stationary and changes sign when the splitter is parallel to the Earth's surface. The vertical distances from the splitter to the mirrors are

the same at this point. The maximum shift occurs when the beam splitter forms angle of 45 degrees with the Earth's surface. In this situation the vertical distance difference is maximum since the first mirror is in vertical direction and second mirror in horizontal direction.

3. There is also a slight dependence on time of day.

The result might have a trivial explanation. The changes of the distance are rather small: of order 10 microns. Suppose that contraction is in question. In TGD framework there are two distances involved: M^4 distance and the distance defined by the induced metric. The M^4 distance between mirror and splitter in vertical position might shorten by a contraction due to the weight of the system. Alternatively the contraction (if contraction is in question) could correspond to a shortening of the length in the induced metric leaving Minkowski distance invariant. One must estimate the shortening due to the weight of the system to clarify this issue.

6.1.2 Estimate for the change of distance implied by elasticity

The elasticity of the steel plate at which the system is mounted induces by its own weight a change of the vertical distance between beam splitter and mirror above it. Since only order of magnitude estimate is in question, the effects of the instruments mounted on the steel plate are not taken into account in the model so that system (steel plate) is effectively one-dimensional.

1. Using standard elasticity theory in one-dimensional situation [D1], one can express the counterpart for Newton's equations for an effectively one-dimensional elastic medium in a static equilibrium under its own gravitational force as

$$E\partial_z^2 u + \rho g = 0 \tag{6.1}$$

Here u denotes displacement, and E is Young's modulus. ρ is the mass density of the medium and g is the acceleration of gravity at the surface of Earth. The equation states that gravitational force is compensated by the atomic forces modeled using a linear force density $f = E\partial_z^2 u$.

2. From this equation one can solve the displacement $u(z)$ as

$$u(z) = -\frac{\rho g z^2}{2E} + bz + c \ . \tag{6.2}$$

At the bottom of the plate one has $u(0) = 0$. If one has also $(du/dz)(0) = b = 0$ implied by the condition that momentum current in the vertical direction vanishes at the upper end, one obtains

$$u(z) = -\frac{\rho g z^2}{2E} \ . \tag{6.3}$$

This gives for the change of the distance between beam splitter and mirror in vertical position the estimate

$$\Delta h = -\frac{\rho g (h_2^2 - h_1^2)}{2E} \ . \tag{6.4}$$

3. A rough estimate for the relevant parameters of the system are following. The height of the steel plate is $h \simeq .5$ m. The height of the beam splitter is $h \simeq .25$ m and the height of the mirror at maximum height is $h \simeq .35$. The density of steel is $\rho \simeq 8 \times 10^3$ kg/m^3. Young's modulus for steel is $E = 2 \times 10^{11} N/m^2$. This gives the estimate $\Delta h = 1.2 \times 10^{-8}$ m, which is by three orders of magnitude smaller than the estimated distance difference.

6.1.3 Schwartschild metric does not explain the result

In the framework of general relativity the only manner to understand these effects is in terms of distance difference along vertical and horizontal directions. This difference would be due to the deviation of the space-time metric from Minkowski metric in such a way that the distance in radial direction is changed due to the presence of gravitational field of Earth.

1. One can start from the Schwartschild metric as an idealized model for the situation outside the surface of Earth (I use units with $c = 1$).

$$\begin{aligned} ds^2 &= Kdt^2 - \frac{1}{K}dr^2 - r^2(d\theta^2 + sin^2(\theta)d\phi^2) \ , \\ K &= 1 - \frac{r_s}{r} \ , \ r_s = 2GM \ . \end{aligned} \tag{6.5}$$

   Here M denotes the mass of Earth and r the distance from the center of mass of Earth. r_s is Schwartschild radius. At the Earth's surface ($r = R$) one has $r_sc^2/R^2 \simeq g = 10 \ m/s^2$, the gravitational acceleration at the surface of Earth. For $M = 0$ one obtains Minkowski metric and no effect.

2. The maximum distance difference x would correspond to

$$\begin{aligned} \frac{x}{l} &= 2\frac{\int_R^{R+l}(\sqrt{\frac{1}{K}} - 1)dr}{l} \ , \\ K &= 1 - \frac{r_s}{r} \ , \ r_s = 2GM \ . \end{aligned} \tag{6.6}$$

   Here r_s denotes the Schwartschild radius and $R \simeq 6371km$ the Earth's radius. $l \sim .1$ m is the Minkowskian distance between beam splitter and mirror. Since the value of K is extremely small, the integral can be evaluated easily and gives (not surprisingly)

$$\frac{x}{l} \simeq \frac{r_s}{R} = \frac{2gR}{c^2} \simeq 1.4 \times 10^{-9} \ . \tag{6.7}$$

   The predicted value is by a factor of order 10^{-5} too small if one assumes $l = .1$ m.

6.1.4 The modification of Schwartschild metric explaining the result

If the finding of Grusenick is real it means that the value of g_{rr} at the Earth's surface is much larger than for Schwartschild metric. One cannot exclude a large deviation of g_{rr} from the prediction of Schwartschild metric also in the case of stars by what is known about planetary orbits. The point is that for exactly circular orbits g_{rr} does not appear at all in the equations determining the orbits since $dr = 0$ holds true for these orbits. For elliptic orbits the effects are in principle visible and Mercury's perihelion shift poses bounds on the deviation.

1. To see what the needed deviation means quantitatively it is convenient to parameterize the deviation as

$$g_{rr} \ \rightarrow \ (1 + \Delta(r))g_{rr} = -(1 + \Delta(r))\frac{1}{K} \ . \tag{6.8}$$

   Restricting the consideration to the free fall near the Earth's surface one can perform the approximation $\Delta(r) \simeq \Delta(R)$. The value of Δ is fixed by the results of the experiment of Grusenick to be of order

$$\Delta(R) \quad \simeq \quad 5\times 10^{-4} \tag{6.9}$$

if the distance between the mirror and beam splitter is taken to be.1 m (the estimate for the distance is by bare eyes from the video).

2. Einstein's equations for a free fall in radial direction give

$$\begin{aligned} \frac{d^2t}{ds^2} + 2\{ {t \atop r\ r} \}\frac{dt}{ds} fracdrds &= 0 \ , \\ g_{tt}(\frac{dt}{ds})^2 + g_{rr}(\frac{dr}{s})^2 &= 1 \ . \end{aligned} \tag{6.10}$$

3. The first equation can be integrated to give

$$\frac{dt}{ds} \quad = \quad \frac{C}{g_{tt}} = \frac{C}{1-K} \ . \tag{6.11}$$

The result is same as for Scwartshcild metric. The constant C is determined by the initial height in free fall.

4. The second equation expresses the conservation of energy. One can solve dr/ds from it in terms of E and g_{rr}. For Schwartschild metric one obtains

$$(\frac{dr}{ds})^2 - \frac{K}{r} \quad = \quad C^2 - 1 \equiv 2E \ . \tag{6.12}$$

The interpretation in terms of energy conservation is obvious. For the modified metric one obtains

$$(\frac{dr}{ds})^2 - (1+\Delta)\frac{K}{r} \quad = \quad (1+\Delta)2E \ . \tag{6.13}$$

The results is same as obtained for Schwartschild metric if the value of the Newton's constant Gandenergy E are replaced with effective values given by

$$G_{eff} \quad = \quad (1+\Delta)G \ , \ E_{eff} = (1+\Delta)E \ . \tag{6.14}$$

5. The dependence on time of day might reflect a similar contribution of the gravitational field of Sun to the gravitational field if the radial component of Sun's gravitational field has similar behavior. From the $1/r$ dependence of Δ the order of magnitude for the additional contribution assuming $\Delta_S(R_S) = \Delta(R)$ (R_S denotes solar radius and r_E the distance of Earth from Sun in the following formula) would be given by

$$\frac{\Delta_S(r_E)}{\Delta(R)} \quad \sim \quad \frac{R_S}{r_E} \sim 4.6\times 10^{-2} \ . \tag{6.15}$$

Therefore the effect of Sun could be visible in the interference pattern and would be maximal when the Sun the measurement point and Sun are at same line and minimal when the normal of Earth is orthogonal to the line connecting Earth with Sun.

For a free fall in a direction orthogonal to the surface of Earth the effect is maximum since g_{rr} is visible in the geodesic equations of motion and means that the effective value of GM estimated in this manner would differ from its actual value. There are several ways, such as Cavendish experiment [E4] to measure G and from the measured value of g to deduce also the value of M. The values of G however vary in surprisingly wide range [E10] with variations up to one per cent. If similar behave holds true also for the gravitational fields of masses used in the experiments determining the value of G, it might be possible to understand these deviations.

6.1.5 What can one conclude about $\Delta(r)$ if the mass density remains zero outside the Earth's surface?

An interesting question is what one can conclude about $\Delta(r)$ by assuming that G^{tt} component for Einstein's tensor remains zero.

1. For a spherically symmetric metric parameterized as

$$ds^2 = Bdt^2 - Adr^2 - r^2 d\Omega^2 \quad (6.16)$$

the expressions for the components of Einstein tensor for spherically symmetric stationary metric are deduced in this this chapter and given by

$$\begin{aligned} G^{rr} &= \frac{1}{A^2}(-\frac{\partial_r B}{Br} + \frac{(A-1)}{r^2}) \ , \\ G^{\theta\theta} &= \frac{1}{r^2}[-\frac{\partial_r^2 B}{2BA} + \frac{1}{2Ar}(\frac{\partial_r A}{A} - \frac{\partial_r B}{B}) \\ &+ \frac{\partial_r B}{4AB}(\frac{\partial_r A}{A} + \frac{\partial_r B}{B}] \ , \\ G^{tt} &= \frac{1}{AB}(-\frac{\partial_r A}{Ar} + \frac{(1-A)}{r^2}) \ . \end{aligned} \quad (6.17)$$

2. In the recent case one obtains

$$\begin{aligned} G^{tt} &= -\frac{1}{(1+\Delta)r^2} \times (\frac{r\partial_r \Delta}{1+\Delta} + \frac{\Delta}{1-\frac{r_s}{r}}) \ , \\ G^{rr} &= \frac{\Delta}{(1+\Delta)r^2}(1-\frac{r_s}{r}) \ , \\ G^{\theta\theta} &= \frac{\partial_r \Delta}{2(1+\Delta)r^3} \times (2 - 3\frac{r_s}{r}) \ , \\ r_s &= 2GM \ . \end{aligned} \quad (6.18)$$

$r_s = 2GM$ denotes Schwartschild radius.

3. If one requires that the mass density outside the Earth's radius vanishes one obtains $G^{tt} = 0$ giving the differential equation

$$\frac{\partial_r \Delta}{\Delta(1+\Delta)} = -\frac{1}{r(1-\frac{r_s}{r}} \ . \quad (6.19)$$

The solution is

$$\Delta(r) = \frac{X}{1-X} \ , \ X = \frac{R}{r} \times \frac{1-\frac{r_s}{R}}{1-\frac{r_s}{r}} \times \frac{\Delta(R)}{1+\Delta(R)} \ . \quad (6.20)$$

The deviation approaches zero like $1/r$. The effects on planetary orbits would be negligible in the case that this expression holds true in case of Sun with same order of magnitude for Δ. Only when the orbits is very near to the surface of the star the situation changes. This situation might prevail for some exoplanets.

4. If the deviation is due the interaction of the massive body with the external world, it is dictated in the first approximation by the average density of matter in cosmos and by the geometry of the body meaning that the function $\Delta(r)$ for $r \gg R$ is universal and therefore same for all systems.

6.1.6 Is the proposal consistent with causality?

The general expressions for the Einstein tensor listed above allow to deduce how the "pressure" components G^{rr} and $G^{\theta\theta}$ of the Einstein tensor are affected. $G^{tt} = 0$ combined with non-vanishing of "pressure" components of $G^{\alpha\beta}$ seems to break causality. It is also at odds with the general wisdom about the structure of a typical energy momentum tensor of matter. The attempt to understand what is involved induces a series of arguments and counter arguments leading to what seems to provide a deeper understanding of Einstein's equations in zero energy ontology and also of the notion of virtual particle as well as the realization of twistor program in TGD framework.

1. In TGD framework one has sub-manifold gravity for which Einstein equations hold true at long length scale limit with the constraint space-time surfaces are extremals of Kähler action. The Schwartschild coordinates (t, r, θ_M, ϕ_M) for the embedding of Schwartschild solution in $M^4 \times CP_2$ are related to Minkowski coordinates (m^0, r_M, θ, ϕ) by the conditions $(m^0 = \Lambda t + h(r_M), r_M = r, \theta_M = \theta, \phi_M = \phi)$. As a consequence, the time component of the energy momentum tensor is non-vanishing in Minkowski coordinates and one might hope that the apparent breaking of causality could be a mere coordinate artefact.

2. A possible general coordinate invariant characterization of the causality would be as the condition $G \geq 0$. In the recent case this condition reads as

$$G = \Delta\left[1 - \frac{1}{(1+\Delta)^2} - \frac{x}{2(1-x)}\right] \geq 0 \ , \ x = \frac{r_s}{r} \ . \tag{6.21}$$

   For small values of Δ the sign of this quantity is determined by the sign of Δ since the first two terms in the brackets cancel each other in good approximation and is positive if Δ is negative. Hence $\Delta \leq 0$ guarantees causality in this sense.

3. In TGD framework one can consider also a stronger form of causality. The vector field $G^{\alpha k} = G^{\alpha r}\partial_r m^k$, where m^k denotes linear coordinates for M^4, is proportional to four-momentum current. It is space-like since $|\partial_r h(r)| < 1$ holds true to guarantee that $t = constant$ 3-surface is space-like so that $G^{\alpha k}$ seems to describe a tachyonic energy momentum current. In quantum context this need not be a catastrophe. Quantum classical correspondence suggests the identification of $G^{\alpha k}$ in the matter free regions as the four-momentum current associated with virtual particles mediating the interactions of the system with the external world. Note that also gravitons must contribute to the energy momentum tensor $T^{\alpha\beta}$ if this is the correct interpretation.

4. It is however very difficult to understand how the energy momentum tensor of matter could behave like $G^{\alpha k}$ does. The resolution of the problem is very simple in zero energy ontology. In zero energy ontology bosons (and their super counterparts) correspond to wormhole contacts carrying fermion and anti-fermion numbers at the light-like wormhole throats and having opposite signs of energy. This allows the possibility that the fermions at the throats are on mass shell and the sum of their momenta gives rise to off mass shell momentum which can be also space-like. In zero energy ontology $G^{\alpha\beta}$ would naturally correspond to the sum of on mass shell energy energy momentum tensors $T_{\pm}^{\alpha\beta}$ associated with positive and negative energy fermions and their super-counterparts. Note that for the energy momentum tensor $T^{\alpha\beta} = (\rho + p)u^\alpha u^\beta - pg^{\alpha\beta}$ of fluid with $u^\alpha u_\alpha = 1$ constraint stating on mass shell condition the allowance of virtual particles would mean giving up the condition $u^\alpha u_\alpha = 1$ for the velocity field.

5. This identification suggests also a nice formulation of the twistor program [K12, **?**]. The basic idea is that massive on mass shell states can be regarded as massless states in 8-dimensional sense so that twistor program generalizes to the case of massive on mass shell states associated with the representations of super-conformal algebras. One has however also now off mass shell states and the question is how to describe them in terms of generalized twistors. In the case of wormhole contacts the answer is obvious. Since bosons and their super partners correspond to pairs of positive and negative energy on mass shell states, both on mass shell

and of mass shell states can be described using a pair of twistors associated with composite momenta massless in 8-D sense.

6. How can one then interpret virtual fermions and their super-counterparts? Fermions and their super-partners have been assumed to consist of single wormhole throat associated with a deformation of CP_2 vacuum extremal so that the proposed definition would allow only on mass shell states. A possible resolution of the problem is the identification of also virtual fermions and their super-counterparts as wormhole contacts in the sense that the second wormhole throats is fermionic Fock vacuum carrying purely bosonic quantum numbers and corresponds to a state generated by purely bosonic generators of the super-symplectic algebra whose elements are in 1-1 correspondence with Hamiltonians of $\delta M^4_\pm \times CP_2$. Thus the distinction between on mass shell and of mass shell states would be purely topological for fermions and their super partners.

   The concrete physical interpretation would be that particle scattering event involves at least two parallel space-time sheets. Incoming (outgoing) fermion is topologically condensed at positive energy (negative energy) sheet and in the interaction region touches with a high probably the other sheet since the distance between sheets is about 10^4 Planck lengths. The touching (topological sum) generates a second wormhole throat with a spherical topology and carrying no fermion number. Virtual fermions would be fermions in interaction region [K12, K1].

The conclusion would be following. A large deviation of the radial component of the metric from empty space metric near Earth's surface could explain the finding claimed by Grusenick without contradictions with what is known about the metric for planetary orbits assuming that similar deviation occurs quite generally. Michelson-Morley interferometer would provide a very precise method to measure g_{rr} at various heights (say in satellites) so that a very precise testing of the proposed model becomes possible. Also the value of g_{rr} of solar gravitational field at Earth's surface might be deduced from the diurnal variation of the interference pattern.

6.2 Various Interpretations Of Machian Principle In TGD Framework

TGD allows several interpretations of Machian Principle and leads also to a generalization of the Principle.

1. Machian Principle is true in the sense that the notion of completely free particle is non-sensible. Free CP_2 type extremal (having random light-like curve as M^4 projection) is a pure vacuum extremal and only its topological condensation creates a wormhole throat (two of them) in the case of fermion (boson). Topological condensation to space-time sheet(s) generates all quantum numbers, not only mass. Both thermal massivation and massivation via the generation of coherent state of Higgs type wormhole contacts are due to topological condensation.

2. Machian Principle has also interpretation in terms of p-adic physics [K10]. Most points of p-adic space-time sheets have infinite distance from the tip light-cone in the real sense. The discrete algebraic intersection of the p-adic space-time sheet with the real space-time sheet gives rise to effective p-adicity of the topology of the real space-time sheet if the number of these points is large enough. Hence p-adic thermodynamics with given p also assigned to the partonic 3-surface by the Kähler-Dirac operator makes sense. The continuity and smoothness of the dynamics corresponds to the p-adic fractality and long range correlations for the real dynamics and allows to apply p-adic thermodynamics in the real context. p-Adic variant of Machian Principle says that p-adic dynamics of cognition and intentionality in literally infinite scale in the real sense dictates the values of masses among other things.

3. A further interpretation of Machian Principle is in terms of number theoretic Brahman=Atman identity or equivalently, Algebraic Holography [K9]. This principle states that the number theoretic structure of the space-time point is so rich due to the presence of infinite hierarchy of real units obtained as ratios of infinite integers that single space-time point can represent the entire world of classical worlds. This could be generalized also to a criterion for a good

mathematics: only those mathematical structures which are representable in the set of real units associated with the coordinates of single space-time point are really fundamental.

6.3 Einstein's Equations And Second Variation Of Volume Element

Jacobsen [B3] has derived Einstein's equations from thermodynamical considerations. The argument involves approximate Poincare invariance, Equivalence principle, and proportionality of entropy to area ($dS = kdA$) so that the result is perhaps not a complete surprise.

One starts from an expression for the variation of the area element dA for certain kind of variations in direction of light-like Killing vector field and ends up with Einstein's equations. Ricci tensor creeps in via the variation of dA expressible in terms of the analog of geodesic deviation involving curvature tensor in its expression. Since geodesic equation involves first variation of metric, the equation of geodesic deviation involves its second variation expressible in terms of curvature tensor.

The result raises the question whether it makes sense to quantize Einstein Hilbert action and in light of quantum TGD the worry is justified. In TGD (and also in string models) Einstein's equations result in long length scale approximation whereas in short length scales stringy description would provide the space-time correlate for Equivalence Principle. It has turned out that GRT limit of TGD can be obtained as effective theory in which M^4 is endowed with an effective metric defined as sum of flat Minkowski metric and sum over the deviations of the effective metrics of various space-time sheets from flat metric. Similar description applies to various gauge fields. Classical form of Equivalence Principle reduces to its formulation in GRT. With this interpretation the quantization of the effective metric does not seem sensical.

In the following I will consider different -more than 10 year old - argument implying that empty space vacuum equations state the vanishing of first and second variation of the volume element in freely falling coordinate system and will show how the argument implies empty space vacuum equations in the "world of classical worlds". I also show that empty space Einstein equations at space-time level allow interpretation in terms of criticality of volume element - perhaps serving as a correlate for vacuum criticality of TGD Universe. I also demonstrate how one can derive non-empty space Einstein equations in TGD Universe and consider the interpretation.

6.3.1 Vacuum Einstein's equations from the vanishing of the second variation of volume element in freely falling frame

The argument of Jacobsen leads to interesting considerations related to the second variation of the metric given in terms of Ricci tensor. In TGD framework the challenge is to deduce a good argument for why Einstein's equations hold true in long length scales and one ends up to an idea how one might understand the content of these equations geometrically.

1. The first variation of the metric determinant gives rise to

$$\delta\sqrt{g} = \partial_\mu\sqrt{g}dx^\mu \propto \sqrt{g}\left(\begin{array}{c} \rho \\ \rho\ \mu \end{array}\right) dx^\mu .$$

   The possibility to find coordinates for which this variation vanishes at given point of space-time realizes Equivalence Principle locally.

2. Second variation of the metric determinant gives rise to the quantity

$$\delta^2\sqrt{g} = \partial_\mu\partial_\nu\sqrt{g}dx^\mu dx^\nu = \sqrt{g}R_{\mu\nu}dx^\mu dx^\nu .$$

   The vanishing of the second variation gives Einstein's equations in empty space. Einstein's empty space equations state that the second variation of the metric determinant vanishes in freely moving frame. The 4-volume element is critical in this frame.

6.3.2 The world of classical worlds satisfies vacuum Einstein equations

In quantum TGD this observation about second variation of metric led for two decades ago to Einstein's vacuum equations for the Kähler metric for the space of light-like 3-surfaces ("world of classical worlds"), which is deduced to be a union of constant curvature spaces labeled by zero modes of the metric. The argument is very simple. The functional integration over WCW degrees of freedom (union of constant curvature spaces a priori: $R_{ij} = kg_{ij}$) involves second variation of the metric determinant. The functional integral over small deformations of 3-surface involves also second variation of the volume element $\sqrt{g}$. The propagator for small deformations around 3-surface is contravariant metric for Kähler metric and is contracted with $R_{ij} = \lambda g_{ij}$ to give the infinite-dimensional trace $g^{ij}R_{ij} = \lambda D = \lambda \times \infty$. The result is infinite unless $R_{ij} = 0$ holds. Vacuum Einstein's equations must therefore hold true in the world of classical worlds.

6.3.3 Non-vacuum Einstein's equations: light-like projection of four-momentum projection is proportional to second variation of four-volume in that direction

An interesting question is whether Einstein's equations in non-empty space-time could be obtained by generalizing this argument. The question is what interpretation one should give to the quantity

$$\sqrt{g_4}T_{\mu\nu}dx^\mu dx^\nu$$

at a given point of space-time.

1. If one restricts the consideration to variations for which dx^μ is of form $k^\mu\epsilon$, where k is light-like vector, one obtains a situation similar to used by Jacobsen in his argument. In this case one can consider the component dP_k of four-momentum in direction of k associated with 3-dimensional coordinate volume element $dV_3 = d^3x$. It is given by

$$dP_k = \sqrt{g_4}T_{\mu\nu}k^\mu k^\nu dV_3 .$$

2. Assume that dP_k is proportional to the second variation of the volume element in the deformation $dx^\mu = \epsilon k^\mu$, which means pushing of the volume element in the direction of k in second order approximation:

$$\frac{d^2\sqrt{g_4}}{d\epsilon^2}\sqrt{g_4}dV_3 = \frac{d^2\sqrt{g_4}}{\partial x^\mu \partial x^\nu}k^\mu k^\nu\sqrt{g_4}dV_3 = \sqrt{g_4}R_{\mu\nu}k^\mu k^\nu dV_3 .$$

   By light-likeness of k^μ one can replace $R_{\mu\nu}$ by $G_{\mu\nu}$ and add also $g_{\mu\nu}$ for light-like vector k^μ to obtained covariant conservation of four-momentum. Einstein's equations with cosmological term are obtained.

That light-like vectors play a key role in these arguments is interesting from TGD point of view since light-like 3-surfaces are fundamental objects of TGD Universe.

6.3.4 The interpretation of non-vacuum Einstein's equations as breaking of maximal quantum criticality in TGD framework

What could be the interpretation of the result in TGD framework.

1. In TGD one assigns to the small deformations of vacuum extremals average four-momentum densities (over ensemble of small deformations), which satisfy Einstein's equations. It looks rather natural to assume that statistical quantities are expressible in terms of the purely geometric gravitational energy momentum tensor of vacuum extremal (which as such is not physical). The question why the projections of four-momentum to light-like directions should be proportional to the second variation of 4-D metric determinant.

2. A possible explanation is the quantum criticality of quantum TGD. For induced spinor fields the Kähler-Dirac equation gives rise to conserved Noether currents only if the second variation of Kähler action vanishes. The reason is that the Kähler-Dirac gamma matrices are contractions of the first variation of Kähler action with ordinary gamma matrices.

3. A weaker condition is that the vanishing occurs only for a subset of deformations representing dynamical symmetries. This would give rise to an infinite hierarchy of increasingly critical systems and generalization of Thom's catastrophe theory would result. The simplest system would live at the V shaped graph of cusp catastrophe: just at the verge of phase transition between the two phases.

4. Vacuum extremals are maximally quantum critical since both the first and second variation of Kähler action vanishes identically. For the small deformations second variation could be non-vanishing and probably is. Could it be that vacuum Einstein equations would give gravitational correlate of the quantum criticality as the criticality of the four-volume element in the local freely falling frame. Non-vacuum Einstein equations would characterize the reduction of the criticality due to the presence of matter implying also the breaking of dynamical symmetries (symplectic transformations of CP_2 and diffeomorphisms of M^4 for vacuum extremals).

REFERENCES

Mathematics

Theoretical Physics

[B1] Martin D. Comments on Cahill's quantum foam inflow theory of gravity, 2004. Available at: https://arxiv.org/pdf/gr-qc/0407059v4.

[B2] Cahill RT. Gravity as Quantum Foam In-Flow, 2003. Available at: https://arXiv.org/abs/physics/0307003.

[B3] Jacobson T. Thermodynamics of Spacetime: The Einstein Equation of State, 1995. Available at: https://arxiv.org/abs/gr-qc/9504004.

Particle and Nuclear Physics

[C1] ICARUS Proves Neutrinos More Than 10 Times Faster Than Light. Available at: https://tinyurl.com/3uk6g7t.

[C2] ICARUS Refutes Opera's Superluminal Neutrinos. Available at: https://tinyurl.com/3q79xnb.

[C3] MINOS, 2011. Available at: https://en.wikipedia.org/wiki/MINOS.

[C4] OPERA fail to find error in Faster Than Light Measurement, 2011. Available at: https://tinyurl.com/o7868kx.

[C5] Nesti F Berezhiani Z. Magnetic anomaly in UCN trapping: signal for neutron oscillations to parallel world? *Eur Phys J C*, 72(1974), 2012. Available at: https://www.springerlink.com/content/h68g501352t57011/fulltext.pdf.

[C6] Glashow SL Cohen AG. New Constraints on Neutrino Velocities, 2011. Available at: https://arxiv.org/abs/1109.6562.

[C7] ICARUS collaboration. A search for the analogue to Cherenkov radiation by high energy neutrinos at superluminal speeds in ICARUS, 2011. Available at: https://arxiv.org/abs/1110.3763.

[C8] Icarus Collaboration. Measurement of the neutrino velocity with the ICARUS detector at the CNGS beam, 2012. Available at: https://arxiv.org/pdf/1203.3433.pdf.

[C9] OPERA collaboration. Measurement of the neutrino velocity with the OPERA detector in the CNGS beam, 2011. Available at: https://arxiv.org/abs/1109.4897.

[C10] McAlpine K. Incredible shrinking proton raises eyebrows, 2010. Available at: https://tinyurl.com/3yf4n77.

Condensed Matter Physics

[D1] Linear elasticity. Available at: https://en.wikipedia.org/wiki/Linear_elasticity.

[D2] Novoselov KS et al. Two-dimensional gas of massless Dirac fermions in graphene. *Nature*, 438, November 2005.

Cosmology and Astro-Physics

[E1] A brief video demonstrating the basic idea of Michelson-Morley experiment. Available at: https://www.youtube.com/watch?v=7T0d7o8X2-E. See also https://www.youtube.com/watch?v=VyePASErr5Q&NR=1.

[E2] Allais effect. Available at: https://en.wikipedia.org/wiki/Allais_effect.

[E3] Bullet Cluster. Available at: https://en.wikipedia.org/wiki/Bullet_cluster.

[E4] Cavendish experiment. Available at: https://en.wikipedia.org/wiki/Cavendish_experiment.

[E5] Cosmic Ether-Drift and Dynamic Energy in Space. Bibliography and Resources. Available at: https://www.orgonelab.org/energyinspace.htm.

[E6] French Nobel Laureate turns back clock: Marshall's global experiment, von Braun memories evoked during August 11 solar eclipse. Available at: https://science.nasa.gov/newhome/headlines/ast12oct99_1.htm.

[E7] Kerr metric. Available at: https://en.wikipedia.org/wiki/Kerr_metric.

[E8] Kilogram. Available at: https://en.wikipedia.org/wiki/Kilogram.

[E9] Michelson-Morley experiment. Available at: https://en.wikipedia.org/wiki/Michelson-Morley.

[E10] The Controversy over Newton's Gravitational Constant. Available at: https://www.npl.washington.edu/eotwash/experiments/bigG/bigG.html.

[E11] Markevitch M Clowe D, Gonzales A. Weak lensing mass reconstruction of the interacting cluster 1E0657-558: Direct evidence for the existence of dark matter, 2003. Available at: https://arxiv.org/astro-ph/0312273.

[E12] Will CM. Confrontation between General Relativity and Experiment, 2006.Available at: https://arxiv.org/PS_cache/gr-qc/pdf/0510/0510072v2.pdf.

[E13] MAGIC collaboration. Probing Quantum Gravity using Photons from a Mkn 501 Flare observed in MAGIC, 2007Available at: https://arxiv.org/abs/0708.2889.

[E14] Everitt CWF. In *Results from Gravity Probe B*, 2007. Available at: https://meetings.aps.org/Meeting/APR07/Event/64567.

[E15] Clove D et al. A direct empirical proof of the existence of dark matter, 2006. Available at: https://arxiv.org/abs/astro-ph/0608407.

[E16] Mihaila I et al. A new confirmation of the Allais effect during the solar eclipse of 31 2003 May, 2003. Available at: https://home.t01.itscom.net/allais/blackprior/mihaila/2003/mihaila2003.pdf.

[E17] Pierce JM et al. *Nature*, 371, 1994.

[E18] Tajmar M et al. Experimental Detection of Gravimagnetic London Moment, 2006. Available at: https://arxiv.org/abs/gr-gc0603033. See also the popular article "Towards new tests of general relativity", at https://www.esa.int/SPECIALS/GSP/SEM0L6OVGJE_0.html.

[E19] Tate J et al. *Phys Rev*, 62(8), 1989.

[E20] Wang Q-S et al. Precise measurement of gravity variations during a total solar eclipse. *Phys Rev D*, 62, 2000. Available at: https://home.t01.itscom.net/allais/blackprior/wang/wangetal.pdf.

[E21] Antonescu V Jeverdan GT, Rusu GI. Experiments using the Foucault pendulum during the solar eclipse of 15 February, 1961. *Bibl Astr*, 1(55), 1981.

[E22] Allais M. Should the Laws of Gravitation Be Reconsidered: Part I,II,III?, 1959. Available at: https://home.t01.itscom.net/allais/blackprior/allais/lawgravit/lawgrav-one.pdf.

[E23] Grusenick M. Extended Michelson-Morley interferometer experiment, 2009. Available at: https://www.youtube.com/watch?v=7T0d7o8X2-E.

[E24] Ulianov PO. The Witte Effect: The Neutrino Speed and The Anisotropy of the Light Speed, as Defined in the General Theory of Relativity, 2011. Available at: https://www.atomlig.com.br/poli/WitteEffect-IG.pdf.

[E25] Olenici D Popescu VA. A confirmation of the Allais and Jeverdan-Rusu-Antonescu effects during the solar eclipse from 22 September 2006, and the quantization behavior of pendulum, 2007. Available at: https://www.hessdalen.org/sse/program/Articol.pdf.

[E26] Cahill RT. Absolute Motion and Gravitational Effects. *Apeiron*, 11:53–111, 2004. Available at: https://redshift.vif.com/JournalFiles/V11NO1PDF/V11N1CA2.pdf.

[E27] Cahill RT. A New Light-Speed Anisotropy Experiment: Absolute Motion and Gravitational Waves Detected. *Progr Phys*, 25:73–92, 2006. Available at: https://arxiv.org/abs/physics/0610076.

[E28] Cahill RT. The Roland De Witte 1991 Experiment (to the Memory of Roland De Witte). *Progr Phys*, 3:60–65, 2006. Available at: https://www.orgonelab.org/EtherDrift/CahillDeWitte2006.pdf.

[E29] Farrar G Springel V. The speed of the 'bullet' in the merging galaxy cluster 1E0657-56, 2007.Available at: https://arxiv.org/abs/astro-ph/0703232.

[E30] Matos de CJ Tajmar M. Local Photon and Graviton Mass and Its Consequences, 2006. Available at: https://arxiv.org/abs/gr-gc0603032.

[E31] Merali Z. Dark Matter gets its own dark force. *New Scientist*, (2587), 2007.

Physics of Earth

[F1] Tides. Available at: https://en.wikipedia.org/wiki/Tides.

Fringe Physics

[H1] OPERA Collaboration. Measurement of the neutrino velocity with the OPERA detector in the CNOS beam, 2011. Available at: https://arxiv.org/abs/1109.4897.

[H2] Pappas PT Obolensky A. Thirty six seconds faster than light. *Electronics and Wireless World*, 1988. Available at: https://wbabin.net/historical/pappas.pdf.

[H3] Giani S. On velocities beyond the speed of light c, 1998. Available at: https://arxiv.org/abs/hep-ph/9712265.

Neuroscience and Consciousness

[J1] Reed D. Conceptual Hurdles to New Millennium Physics. *Explore!*, (1), 2003.

[J2] Chernobrov V. Experiments on the Change of Direction and Rate of Time Motion. In *Proc. of III Int. Conf. On Problems of Space, Time, and Gravitation. Russian Academy of Sci s, St. Petersburg, Russia*, 1996.

Books related to TGD

[K1] Pitkänen M. About twistor lift of TGD? In *Quantum TGD: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/hgrtwistor.pdf, 2023.

[K2] Pitkänen M. Anomalies Related to the Classical Z^0 Force and Gravitation. In *TGD and Fringe Physics.* *https://tgdtheory.fi/tgdhtml/Bfreenergies.html*. Available at: https://tgdtheory.fi/pdfpool/Zanom.pdf, 2023.

[K3] Pitkänen M. Basic Extremals of Kähler Action. In *Physics in Many-Sheeted Space-Time: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/class.pdf, 2023.

[K4] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegdark.pdf, 2023.

[K5] Pitkänen M. New Physics Predicted by TGD: Part I. In *p-Adic Physics.* *https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/TGDnewphys1.pdf, 2023.

[K6] Pitkänen M. Quantum Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/qastro.pdf, 2023.

[K7] Pitkänen M. TGD and Astrophysics. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/astro.pdf, 2023.

[K8] Pitkänen M. TGD and Cosmology. In *Physics in Many-Sheeted Space-Time: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdclass2.html*. Available at: https://tgdtheory.fi/pdfpool/cosmo.pdf, 2023.

[K9] Pitkänen M. TGD as a Generalized Number Theory: Infinite Primes. In *TGD as a Generalized Number Theory: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/visionc.pdf, 2023.

[K10] Pitkänen M. TGD as a Generalized Number Theory: p-Adicization Program. In *Quantum Physics as Number Theory: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdnumber1.html*. Available at: https://tgdtheory.fi/pdfpool/visiona.pdf, 2023.

[K11] Pitkänen M. TGD View about Coupling Constant Evolution. In *Quantum TGD: Part II.* *https://tgdtheory.fi/tgdhtml/Btgdquantum2.html*. Available at: https://tgdtheory.fi/pdfpool/ccevolution.pdf, 2023.

[K12] Pitkänen M. The classical part of the twistor story. In *Quantum TGD: Part III.* *https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistorstory.pdf, 2023.

[K13] Pitkänen M. The Relationship Between TGD and GRT. In *Physics in Many-Sheeted Space-Time: Part I.* *https://tgdtheory.fi/tgdhtml/Btgdclass1.html*. Available at: https://tgdtheory.fi/pdfpool/tgdgrt.pdf., 2023.

[K14] Pitkänen M. WCW Spinor Structure. In *Quantum Physics as Infinite-Dimensional Geometry.* *https://tgdtheory.fi/tgdhtml/Btgdgeom.html*. Available at: https://tgdtheory.fi/pdfpool/cspin.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. Are neutrinos superluminal? Available at: https://tgdtheory.fi/public_html/articles/speedofneutrino.pdf., 2011.

[L2] Pitkänen M. CMAP representations about TGD, and TGD inspired theory of consciousness and quantum biology. Available at: https://www.tgdtheory.fi/tgdglossary.pdf., 2014.