Quantum Fluctuations In Geometry As A New Kind Of Noise?

M. Pitkänen
Email: matpitka6@gmail.com.
http://tgdtheory.com/public_html/.

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Abstract

Gravitational detectors in GEO600 experiment have been plagued by unidentified noise in the frequency range 300-1500 Hz Craig J. Hogan has proposed an explanation in terms of holographic Universe. By reading the paper I learned that assumptions needed might be consistent with those of quantum TGD. Light-like 3-surfaces as basic objects, holography, effective 2-dimensionality, are some of the terms appearing repeatedly in the article. The model contains some unacceptable features such as Planck length as minimal wave length in obvious conflict with Lorentz invariance.

Towards the end of year 2015 I realized that the diffraction analog serving as the starting point in Hogan's model cannot be justified in TGD framework. Fortunately, diffraction can be replaced by diffusion emerging very naturally in TGD framework and finally allowing to understand how Planck length emerges from TGD framework, where CP_2 size is the fundamental length parameter. The noise can be also seen as support for the hierarchy of Planck constants.

1 Introduction

The motivation for writing the original variant of this section came from the email of Jack Sarfatti. I learned that gravitational detectors in GEO600 experiment have been plagued by unidentified noise in the frequency range 300-1500 Hz [E3]. Craig J. Hogan has proposed an explanation in terms of holographic Universe [E1]. By reading the paper I learned that assumptions needed might be consistent with those of quantum TGD. Light-like 3-surfaces as basic objects, holography, effective 2-dimensionality, are some of the terms appearing repeatedly in the article [K2]. The model contains some unacceptable features such as Planck length as minimal wave length in obvious conflict with Lorentz invariance.

Towards the end of year 2015 I rewrote the article since I realized that the diffraction analog serving as the starting point in Hogan's model cannot be justified in TGD framework. Fortunately, diffraction can be replaced by diffusion emerging very naturally in TGD framework and finally allowing to understand how Planck length emerges from TGD framework, where CP_2 size is the fundamental length parameter.

Consider first the graviton detector used in GEO600 experiment. The detector consists of two long arms (the length is 600 meters)- essentially rulers of equal length. The incoming gravitational wave causes a periodic stretch of the arms: the lengths of the rulers vary. The detection of gravitons means that laser beam is used to keep record about the varying length difference. This is achieved by splitting the laser beam into two pieces using a beam splitter. After this the beams travel through the arms and bounce back to interfere in the detector. Interference pattern tells whether the beam spent slightly different times in the arms due to the stretching of arm caused by the incoming gravitational radiation. The problem of experimenters has been the presence of an unidentified noise in the range 100-1500 Hz.

The prediction of the article *Measurement of quantum fluctuations in geometry* by Craig Hogan [E1] is that holographic geometry of space-time should induce fluctuations of classical geometry with a spectrum which is completely fixed. Hogan's prediction is very general and - if I have understood correctly - the fluctuations depend only on the duration (or length) of the laser beam using Planck length as a unit. Note that there is no dependence on the length of the arms and the fluctuations characterize only the laser beam. Although Planck length appears in the formula, the fluctuations need not have anything to with gravitons but could be due to the failure of the classical description of laser beams. The great surprise was that the prediction of Hogan for the noise is of the same order of magnitude as the unidentified noise bothering experiments in the range 100-700 Hz.

In the following I will discuss Hogan's model and consider two alternative TGD based explanations for the observations (assuming that they are real).

2 Hogan's Theory

Let us try to understand Hogan's theory in more detail.

1. The basic quantitative prediction of the theory is very simple. The spectral density of the noise for high frequencies is given by $h_H = t_P^{1/2}$, where $t_P = (\hbar G)^{1/2}$ is Planck time. For low frequencies h_H is proportional to 1/f just like 1/f noise. The power density of the noise is given by t_P and a connection with poorly understood 1/f noise appearing in electronic and other systems is suggestive. The prediction depends only Planck scale so that it should very easy to kill the model if one is able to reduce the noise from other sources below the critical level $t_P^{1/2}$. The model predicts also the distribution characterizing the uncertainty in the direction of arrival for photon in terms of the ratio l_P/L. Here L is the length or beam of equivalently its duration. A further prediction is that the minimal uncertainty in the arrival time of photons is given by $\Delta t = (t_P t)^{1/2}$ and increases with the duration of the beam.

2. Both quantum and classical mechanisms are discussed as an explanation of the noise. Gravitational holography is the key assumption behind both models. Gravitational holography states that space-time geometry has two space-time dimensions instead of three at the fundamental level and that third dimension emerges via holography. A further assumption is that light-like (null) 3-surfaces are the fundamental objects.

2.1 Heuristic argument

The model starts from an optics inspired heuristic argument.

1. Consider a light ray with length L, which ends to aperture of size D. This gives rise to a diffraction spot of size $R = \lambda L/D$. The resulting uncertainty of the transverse position of source is minimized when the size of diffraction spot is same as aperture size: $R = D$. This gives for the transverse uncertainty of the position of source $\Delta x = R = D = (\lambda L)^{1/2}$. The orientation of the ray can be determined with a precision $\Delta\theta = (\lambda/L)^{1/2}$. The shorter the

wavelength the better the precision. Planck length is believed to pose a fundamental limit to the precision. The conjecture is that the transverse indeterminacy of Planck wave length quantum paths corresponds to the quantum indeterminacy of the metric itself. What this means is not quite clear to me.

2. The basic outcome of the model is that the uncertainty for the arrival times of the photons after reflection is proportional to

$$\Delta t = t_P^{1/2} \times (sin(\theta))^{1/2} \times sin(2\theta) \ ,$$

where θ denotes the angle of incidence on beam splitter. In normal direction Δt vanishes. The proposed interpretation is in terms of Brownian motion for the distance between beam splitter and detector the interpretation being that each reflection from beam splitter adds uncertainty. This is essentially due to the replacement of light-like surface with a new one orthogonal to it inducing a measurement of distance between detector and bean splitter.

This argument has some aspects which I find questionable.

1. The assumption of Planck wave length waves is certainly questionable. The underlying assumption is that it leads to the classical formula involving the aperture size which is eliminated from the basic formula by requiring optimal angular resolution. One might argue that a special status of waves with Planck wave length breaks Lorentz invariance but since the experimental apparatus defines a preferred coordinate system this ned not be a problem.

2. Unless one is ready to forget the argument leading to the formula for $\Delta\theta$, one can argue that the description of the holographic interaction between distant points induced by these Planck wave length waves in terms of aperture with size $D = (l_P L)^{1/2}$ (of order proton Compton length for $L = 10^4$ meters) should have some more abstract physical counterpart.

   Could elementary particles as extended 2-D objects (as in TGD) play the role of ideal apertures to which a radiation with Planck wave length arrives? In this case L would be optimized. If one gives up the assumption about Planck wave radiation the uncertainty increases as λ. To my opinion one should be able to deduce the basic formula without this kind of argument.

   Could Planck length correspond ib TGD framework to the uncertainty for the position of the fermion lines associated with the generalized Feynmann graphs defined by light-like orbits of wormhole throats?

2.2 Argument based on Uncertainty Principle for waves with Planck wave length

Second argument can do without diffraction but still uses the highly questionable Planck wave length waves.

1. The interactions of Planck wave length radiation at null surface at two different times corresponding to normal coordinates z_1 and z_2 at these times are considered. From the standard uncertainty relation between momentum and position of the incoming particle one deduces uncertainty relation for transverse position operators $x(z_i)$, i=1, 2. The uncertainty comes from uncertainty of $x(z_2)$ induced by uncertainty of the transverse momentum $p_x(z_i)$. The uncertainty relation is deduced by assuming that $(x(z_2) - x(z_1)/(z_2 - z_1)$ is the ratio of transversal and longitudinal wave vectors. This relates $x(z_2)$ to $p_x(z_i)$ and the uncertainty relation can be deduced. The uncertainty increases linearly with $z_2 - z_1$. Geometric optics is used to describe the propagation between the two points and this should certainly work for a situation in which wavelength is Planck wavelength if the notion of Planck wave length wave makes sense. From this formula the basic predictions follow.

2. Hogan emphasizes that the basic result is obtained also classically by assuming that light-like surfaces describing the propagation of light between ends points of arm describe Brownian like random walk in directions transverse to the direction of propagation. Does this mean that Planck wave length wave is not absolutely necessary for this approach.

I admit that I find it difficult to follow the arguments.

2.3 Description in terms of equivalent gravitonic wave packet

Hogan discusses also an effective description of holographic noise in terms of gravitational wave packet passign through the system.

1. The holographic noise at frequency f has equivalent description in terms of a gravitational wave packet of frequency f and duration $T = 1/f$ passing through the system. In this description the variance for the length difference of arms using standard formula for gravitational wave packet is given by

$$\frac{\Delta l^2}{l^2} = h^2 f \ ,$$

   where h characterizes the spectral density of the gravitational wave. This is extremely small number requiring l to be macroscopic length so that amplification from Planck lengths takes place.

2. For high frequencies one obtains

$$h = h_P = (t_P)^{1/2} \ .$$

3. For low frequencies the model predicts

$$h = \frac{(f_{res}}{f}(t_P)^{1/2}.$$

   Here f_{res} characterized the inverse residence time in detector and is estimated to be about 700 Hz in GEO600 experiment.

4. The predictions of the theory are compared to the unidentified noise in the frequency range 100-600 Hz which introduces amplifying factor varying from 7 to 1. The orders of magnitude are same.

3 TGD Based Model

Planck length as a minimal wavelength is in sharp conflict with Lorentz invariance. This is the fatal failure of the model for the claimed noise relying on diffraction as analog phenomenon. TGD approach suggests that diffusion in degrees of freedom transversal to light-orbits of partonic 2-surfaces representing particle orbits is a more promising analogy to start with.

3.1 Some background

Consider first the general picture behind the TGD inspired model.

1. What authors emphasize can be condensed to the following statement: *The transverse indeterminacy of Planck wave length seems likely to be a feature of 3+1 D space-time emerge is as a dual of quantum theory on a 2+1-D null surface.* In TGD light-like 3-surfaces indeed are the fundamental objects and 4-D space-time surface is in a holographic relation to these light-like 3-surfaces. The analog of conformal invariance in light-like radial direction implies that partonic 2-surfaces are actually basic objects in short scales in the sense that one 3-dimensionality only in discretized sense.

2. Both the interpretation as almost topological quantum field theory, the notion of finite measurement resolution, number theoretical universality making possible p-adicization of quantum TGD, and the notion of quantum criticality lead to a fundamental description in terms of discrete points sets. These are defined as intersections of what I call number theoretic braids with partonic 2-surfaces X^2 at the boundaries of causal diamonds identified as intersections of future and paste directed light-cones forming a fractal hierarchy. These 2-surfaces X^2 correspond to the ends of light-like three surfaces. Only the data from this discrete point

set is used in the definition of M-matrix: there is however continuum of selections of this data set corresponding to different directions of light-like ray at the boundary of light-cone, and in detection one of these direction is selected and corresponds to the direction of beam in the recent case.

3. Fermions correspond to CP_2 type vacuum extremal with Euclidian signature of induced metric condensed to space-time sheet with Minkowskian signature and light-like wormhole throat for which 4-metric is degenerate carries the quantum numbers. Bosons correspond to wormhole contacts consisting of a piece of CP_2 vacuum extremal connecting two two space-time sheets with Minkowskian signature of induced metric. The strands of number theoretic braids carry fermionic quantum numbers and discretization is interpreted as a space-time correlate for the finite measurement resolution implying the effective grainy nature of 2-surfaces.

3.2 How to end up with TGD inspired model?

TGD does not seem to provide a justification for the models based on diffraction as physical phenomenon behind the noise.

1. Could one assign Planck wave length with the light-like orbit of partonic 2-surface involving periodic variation of CP_2 coordinates characerized by Planck length? Here the problem is that CP_2 length which is 10^4 times longer seems more natural guess for the minimum wavelength in this sense. For shorter wavelengths induced metric changes signature as simple ansatz shows.

2. Planck wave length as minimum wavelength means breaking of Lorentz invariance. Generalized Feynman diagrams correspond to space-time regions with Euclidian signature of induced metric- wormhole contacts typically. Elementary particles correspond to pairs of wormhole contacts. Could one assign the Planck length as wavelength to a periodic variation of angle-like CP_2 coordinate inside wormhole contact? One would could avoid problems with Lorentz invariance and maybe the diffraction picture would make sense inside Euclidian regions. The problem is that wave motion is impossible in Euclidian signature.

3. Could Planck length correspond to the position uncertainty section of so called massless extremals (MEs) assignable to MEs and orthogonal to the direction of propagation. Or could one interpret Planck length as uncertainty for the transverse position of the fermionic lines entering the diffraction slit? This however forces to give up the diffraction picture and formulas become just dimensional arguments.

Could diffusion replace diffraction as starting point?

1. Could one begin directly from the formula $\Delta x = R = D = \sqrt{l_P L}$. This would allow also to avoid problems with Lorentz invariance coming from the idea of minimum wavelength. One would give up the interpretation of l_P as wavelength so that the formula would be just dimension analytic guess and therefore unsatisfactory.

2. Could one assign Δx to the randomness of the light-like orbit of wormhole contact/partonic 2-surface/fermionic line at it. Δx would represent the randomness of the transversal coordinate for light-like parton orbit. This randomness could be also assigned to the light-like curves defining fermion lines at the orbits of partonic 2-surfaces. Diffusion would provide the physical analogy rather than diffraction.

   $T = L/c$ would correspond to time and $\Delta x = R = D$ would be analogous to the mean square distance $\langle r^2 \rangle = DT$. $D = c^2 t_P$, diffused during time T. This would also conform qualitatively with the basic idea of p-adic thermodynamics. One would also find the long sought interpretation of Planck length in TGD framework where CP_2 length scale is the fundamental length scale.

3. Why the noise would appear at certain frequency range? A possible explanation is that large Planck constants are involved. The ratios of the frequency f_h of laser beam to the relatively

low frequencies f_l in the frequency range of noise corresponds to the spectrum of Planck constants $h_{eff} = f_h/f_l$ involved? Maybe low frequencies could correspond to bunches of dark low energy photons with total energy equal to that of laser photon. Dark photons could relate to the long range correlations inside laser beam.

The presence of large values of Planck constants suggests strongly quantum criticality, which should relate to laser beam. Could one assign the long range correlations of laser beam with quantum criticality realized as spectrum of Planck constants?

3.3 Large h_{eff} gravitons do not explain the claimed anomaly

In [K1] I have proposed that part of gravitons could arrive as large h_{eff} gravitons having same frequency as ordinary gravitons but by a factor h_{eff}/h higher energy, and thus have much larger effect than ordinary gravitons. They could transfrom with some probability to ordinary very high energy gravitons or decay to a bunch of $h_{eff}/h = n$ ordinary gravitons with the same frequency.

The additional assumption is $h_{eff} = h_{gr} = GMm/v_0$, where M is mass of the source of gravitations, m the mass of the receiver particle (elementary particle, most naturally proton), and v_0 is some characteristic velocity parameter associated with the source, characterizes the Kähler magnetic flux tubes along which dark gravitons arrive.

Dark gravitons could be detected in two manners. They could transform to ordinary gravitons but with much larger energy and absorbed by oscillator like system. This detection mechanism would be purely quantal. If the value of h_{gr} is of same order of magnitude as the model for bio-photons as decay products of dark photons suggests, the energy of "bio-graviton" would be in range of visible and UV energies. Bio-.gravitons could be important in living matter.

Second option is that dark graviton decays to a bunch of h_{eff}/h ordinary gravitons, which because of their large number define a semiclassical state (large n limit for a harmonic oscillator corresponds to quasiclassical state). In semiclassical approximation one would have a classical gravitational wave with amplitude defined by oscillator state containing $n = h_{eff}/h = GMm/v_0h$ gravitons. Since n is large, the oscillator state allows an approximation as classical gravitational wave with amplitude scaled up by $\sqrt{n}$ from its value for ordinary value of Planck constant. The amplitude would be by a factor $\sqrt{GMm/v_0h}$ for the oscillation amplitude of distance between the ends of the arm of the detector would scale up by a factor $\sqrt{Gmm/v_0h}$, which is of order 10^{11} for M of order solar mass, m proton mass and $v_0/c \simeq 10^{-3}$. If the amplitude for oscillation of distance between ends of arm is about 10^{-17} meters, it would be amplified to cell scale 10^{-6} meters, perhaps not an accident.

This kind of bunches of ordinary gravitons would be interpreted as noise in GRT framework. The noise in above sense cannot correspond to dark gravitons.

4 Hogan's formula again

My interest to the claimed unidentified noise modelled by Hogan was re-stimulated eight years later as Bee (http://backreaction.blogspot.fi/2015/12/what-fermilabs-holometer-experiment.html told in rather critical tone about an article titled "Search for Space-Time Correlations from the Planck Scale with the Fermilab Holometer" reporting the results of Fermilab experiment [E2]

The claim of Craig Hogan, who leads the experimental group, is that that the experiment is able to demonstrate the absence of quantum gravity effects. The claim is based on a dimensional estimate for transversal fluctuations of distances between mirrors reflecting light - it seems to be essentially the same as discussed in detail above. The fluctuations of the distances between mirrors would be visible as a variation of interference pattern and the correlations of fluctuations between distant mirrors could be interpreted as correlations forced by gravitational holography. No correlations were detected and the brave conclusion was that predicted quantum gravitational effects are absent.

Although no quantitative theory for the effect exists, the effect is expected to be extremely small and non-detectable by quantum holographists. Hogan has however different opinion based on his view about gravitational holography not shared by workers in the field (such as Lenny Susskind). This of course need not mean that his formulate might not be correct!

One has volume size R and the area of of its surface gives bound on entanglement entropy implying that fluctuations must be correlated. A very naive dimensional order of magnitude estimate would suggest that the transversal fluctuation of distance between mirrors (due to the fluctuations of space-time metric) would be given by $\langle \Delta x^2 \rangle \sim (R/l_P) \times l_P^2$. For macroscopic R this could be measurable number. In the above application R becomes the length of the laser beam. This estimate is of course ad hoc, involves very special view about holography, and also Planck length scale mysticism is involved. There is no theory behind it as Bee correctly emphasizes. Therefore the correct conclusion of the experiments would have been that the formula used is very probably wrong.

4.1 How the view of Hogan about holography is wrong?

Why I saw the trouble of writing comments about this was that I want to try to understand what is involved and maybe make some progress in understanding TGD based holography to the GRT inspired holography. The somewhat polarized comment went as follows.

1. The argument of Hogan involves an assumption, which seems to be made routinely by quantum holographists: the 2-D surface involved with holography is *outer* boundary of macroscopic system and bulk corresponds to its interior. This would make the correlation effect large for large R if one takes seriously the dimensional estimate large for large R. The special role of outer boundaries is natural in AdS/CFT framework. In the actual situation however R is replaced with the length of beam so that the situation need not have much to do with holography.

2. In TGD framework outer boundaries do not have any special role. For strong form of holography (SH) the surfaces involved are string world sheets and partonic 2-surfaces serving as "genes" from which one can construct space-time surfaces as preferred extremals by using infinite number of conditions implying vanishing of classical Noether charges for sub-algebra of super-symplectic algebra.

   For weak form of holography one would have 3-surfaces defined by the light-like orbits or partonic 2-surfaces: at these 3-surfaces the signature of the induced metric changes from Minkowskian to Euclidian and they have partonic 2-surfaces as their ends at the light-like boundaries of causal diamonds (CDs). For SH one has at the boundary of CD fermionic strings and partonic 2-surfaces. Strings serve as geometric correlates for entanglement and SH suggests a map between geometric parameters - say string length - and information theoretic parameters such as entanglement entropy.

3. The typical size of the partonic 2-surfaces is CP_2 scale about 10^4 Planck lengths for the ordinary value of Planck constant. The naive scaling law for the the area of partonic 2-surfaces would be $A \propto h_{eff}^2$, $h_{eff} = n \times h$. An alternative form of the scaling law would be as $A \propto h_{eff}$. CD size scale T would scale as h_{eff} and p-adic length scale as its square root (diffused distance R satisfies $R \sim L_p \propto T^{1/2}$ in diffusion; p-adic length scale would be analogous to R).

4. The most natural identification of entanglement entropy would be as entanglement entropy assignable with the *union* of partonic 2-surfaces for which the light-like 3-surface representing generalized Feynman diagram is connected. Entanglement would be between ends of strings beginning from different partonic 2-surfaces. There is *no* bound on the entanglement entropy associated with a given Minkowski 3-volume coming from the area of its *outer* boundary since interior can contain very large number of partonic 2-surfaces contributing to the area and thus entropy. As a consequence, the correlations between fluctuations are expected to be weak.

5. Just for fun one can feed numbers into the proposed dimensional estimate, which of course does not make sense now. For R about of order CP_2 size it would predict completely negligible effect for ordinary value of Planck constant: this entropy could be interpreted as entropy assignable to single partonic 2-surface. Same is true if R corresponds to Compton scale of elementary particle.

This argument demonstrates how sensitive the quantitative estimates are for the detailed view about what holography really means. Loose enough definition of holography can produce endless number of non-sense formulas and it is quite possible that AdS/CFT modelled holography in GRT is completely wrong.

The difference between TGD based and GRT inspired holographies is forced by the new view about space-time allowing also Euclidian space-time regions and from new new view about General Coordinate Invariance implying SH. This brings in a natural identification of the 2-surfaces serving as holograms. In GRT framework these surfaces are identified in ad hoc manner as outer surfaces of arbitrarily chosen 3-volume.

4.2 Why the formula used by Hogan could be partially correct after all?

After I had went through the earlier model for the claimed noise and modified it in some respects, I had still unpleasant feeling that I have not understood everything. TGD predicts the noise and it could be called quantum gravitational. The earlier experiment provides a support for its existence but the recent experiment does not.

How does the earlier experiment reporting unidentified fluctuations and interpreted in the proposed manner in TGD framework relate to the recent experimental finding reporting no fluctuations? I am not experimentalists but the experimental situations look very much the same.

The simplest explanation emerging from quantum criticality in TGD sense is that the frequency range studied in Fermilab experiment does not correspond to the frequencies made possible by the available spectrum of Planck constants. If I have understood correctly, the range corresponds to considerably higher frequencies than the range 300-1500 Hz for the noise detected in the original experiments.

I do not know whether people have been able to eliminate the noise reported in the motivating article [E3]. I hope not! It is unclear whether how the model relates to the Hogan's later model proposing that the correlations implied by holography as he interprets it, are not found. Certainly the idea that Planck wave length waves would be amplified to observable noise does not make sense in TGD framework. It is diffusion of fermion lines in transversal degrees of freedom of light-like random orbits of partonic 2-surfaces serving as a signature of non-point-likeness of fundamental objects, which would become visible as noise. The effect could also seem as signature for the hierarchy of Planck constants and also to quantum gravitational holography.

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