Granular Space–time: The Nature of Time

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Abstract

Granular space-time posits that everything can be expressed as a function of space-time and matter. And this includes the quantum wave function Ψ. To give a geometric interpretation of Ψ, we first need to examine time. The fact that the wave function is complex results in the time dimension also being complex with the imaginary component being rolled-up. The symmetry of time is deduced.

Introduction

A much earlier paper[Frederick 1] pointed out that vacuum energy fluctions were equivalent to mass fluctuations. And those would generate stochastic fluctuations of the metric tensor. That was interpreted as saying that the 'points' (events) of space-time moved in relation to other points. Those mobile points nevertheless continued to tessilate the space-time manifold

A later paper[Frederick 2] noted that a point has no extent and that would make tessilating of space-time problematic. A granular model was the proposed. The granules (called 'venues' to distinguish them from 'events') were taken to be four dimensional; Planck length cubed by Planck time. The two papers were able to generate many of the results of quantum mechanics.

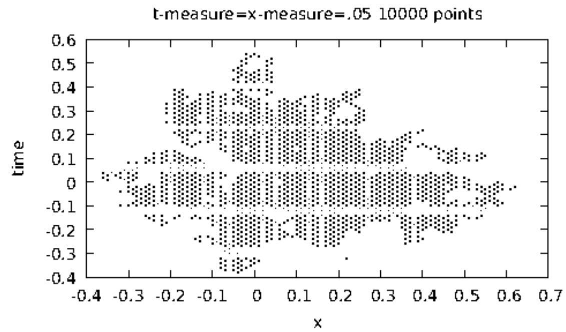
The granular model takes as given that all of physics can be described by properties of space-time and matter. *(and fields and potentials, but we feel those can also be expressed as properties of space-time and matter and constraints determined by matter).* If that is true, then the solutions of the Schrödinger equation, the wave function, should also have a geometric representation. To find it, we must first consider the nature of time.

Time

We'll start with a crude idea of time and methodically sculpt it into a (it is to be hoped) attractive model. We begin with the proposition that venues are stocastically migrating in all directions; x,y,z and also t.

'Time Leaves No Tracks'

Consider the graph (of 1000 points) below. (The vertical and horizontal lines are artifacts of the graphing software.) The graph represents the path of a a single venue migrating in x and also in t, where the coordinate axes are laboratory x and laboratory t.



There is an immediate problem:

Consider what this graph signifies: At any given laboratory-time t, the same venue will (simultaneously) be at a very large number of x coordinates. If there were mass/energy at the venue, this would be very problematic as causality and conservation of mass would be violated.

We'd like to treat the time dimension, t, in the same way as we treat spacial dimensions. But there is a big difference between a space and time coordinate: Consider the graphic below:

A particle (the black disk) starts at x=0, then moves to x=1, then 2, then 3. (We are considering space-time to be granular, hence the coordinate boxes.) There is a single instance of the particle.

But time is different:

A particle at rest is at t=0, then moves to t=1, etc. But when it goes from t=0 to t=1, it also remains at t=0. There are now two instances of the particle, etc. In other words, a particle at a particular time is still there as time advances, and the particle is at the advanced time as well.

We define then, a new quantity, τ (tau-time), that acts much like the usual time, but in accord with the first graphic, above, i.e. when the particle advances in time, it erases the previous instance. That is to say, 'τ-Time Leaves No Tracks'. Aside from fixing the problem of the same mass appearing at an enormous number of different locations at the same time, τ will be seen to provide a solution to the collapse of the wave-function problem.

In our model then, the time leaves no tracks concept implies that there are multiple futures, and they all 'happen'. (This is somewhat redolent of the Everett many-world interpretation[Frederick 4].) An observation from the laboratory will select a particular future (making a track). In general, one can predict the future and also (strange as it sounds) predict the past.

The Emergence of Time as We Know it

We assume that venues migrate stochastically in x,y,z,and t. And the probabilities of migrating in one direction is the same as in the opposite direction. And this applies to t as well as to x,y,z. So at this juncture there is no arrow of time. But now consider a very small symmetry breaking for t, so that the probability of a venue going forward in time is 50.0000...1 percent and 49.9999...9 percent probability of going backward in time. This is so close to equal probabilities as to be effectively equal probabilities.

Now consider two venues bound together by mass. We suggest that it is mass that causes venues to clump together. In this case, the probabilities of migrating in one direction are the same as migrating in the other direction. If this were not the case, the venues (each holding a small amount of mass) would be ripped apart.

The probability of the venues progressing forward in time versus going backward is very slightly greater than in the single venue case. This is easy to see. For example, suppose the single venue probabilities are two thirds forward and one third backward, a ratio of two to one. For two venues the probabilities are four ninths forward and one ninth backward, a ratio of four to one. For each venue added to the clump, the ratio increases. So that when the clump is large enough to be non-negligable, e.g. at the quantum particle scale, the arrow of time (for that clump) is all but completly forward.

Mass then, determines the arrow of time.

There is a problem. When do the migrations occur. Whenness is something of an amorphous concept when time itself is migrating. A two-component time (see below) could provide a solution.

The Dual Nature of Time

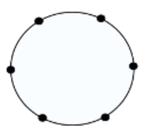
'Time' can be considered to have two characteristics: a coordinate (τ) from minus to plus infinity (or from the big bang to some end of time), and a sequencer (υ), an ordering schema as described by H. Reichenbach[Reichenbach]. determining the direction and 'speed' of time.

So for migrations in time as well as space, we need two kinds of time: coordinate time (as in x,y,z, and t), and sequential time (a measure of something coming before or after something else, and the interval between them).

Our approach will be to decompose time (total time, $\bar{\mathbf{t}}$ which we call t-bar) into coordinate time t_c and sequential time τ. We'll model sequential time, and then combine the two times back into total time.

We consider coordinate time in the usual way, a linear coordinate that runs from minus to plus infinity. But, since there are posited to be no times shorter than a Planck time, instead of a mathematical line, coordinate time is an ordered set of points one Planck time apart. The sequencer implies that all venues are in constant motion. *Omnia mutantur* (all things change) as Ovid puts it.

For sequencing, we merely need to know what event comes before or after another (i.e. the sequence and whether the sequence goes up or down), and the time interval (a single Planck time). A section of a line would do. But there doesn't seem to be any use for a zero of the sequence, nor infinity either. The zero seems arbitrary. (With zero and infinity, the sequence would be more like a coordinate.) So this suggests a circle rather than a line--an angle measure would suffice, i.e. a phase.



τ time

There is a problem with the above. If the radius is t_p the 'arcs' between the sequence points, also t_p, will not overlap as the sequence advances more than one circumference. (i.e. in the above diagram, if the radius is one Planck time, the 'arcs' between the points can't be one Planck time.) And we'll need that overlap. At this scale though, we cannot really define a circle as there can be no 'arcs' at the Planck scale. But we can define the equivalent of a circle, as follows:

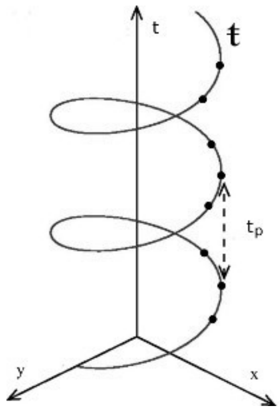
τ time (a better representation).

And with this regular hexagon, the 'arc' lengths equal the radius, so we get overlap. (And here π_p, Planck pi, is a convenient 3.0)

We will presently represent time as $\bar{\mathbf{t}} = t_c e^{i\tau}$ where τ is sequence time. (We could then represent $\bar{\mathbf{t}}$ squared, as for instance in ds^2 as $\bar{\mathbf{t}}^*\bar{\mathbf{t}}$.)[1]

But while we'll be using complex time, a purely real representation has some conceptual advantages. Consider the following: (The idea is to recombine sequence and coordinate times into one real coordinate.)

[1] NOTE: Imaginary time is not unheard of in quantum mechanics: The Diffusion equation with imaginary time becomes the Schrödinger equation. And our QM model is diffusion of space-time (venues). For Stephen Hawking no real distinction exists between 'real' and 'imaginary' time. He recommends, in line with his instrumentalist philosophy, that we should adopt a notion of time, which leads to the best description of physical reality (quoted in "The March of Time" Friedel Weinert, Springer 2013). Imaginary time has also been explored by Neil Turok (Quantum Theory: A Two-Time Success Story, Springer, 2014) and and Dmitri Sokolovski (Time in Quantum Mechanics, Vol 1, Springer 2008)



We could represent **t**=(t_c,τ) as a single time coordinate, not as a line, but as a helix. t_c is the center of the helix, here marked as t (the coordinate for time in the macro-world). The 'rungs' of the helix are one Planck time apart. Whenever there is a time migration, time goes either up or down one rung, leaving the sequencing unchanged. The helix should be considered, not as circular in nature, but hexagonal as in the above representation of τ (sequence) time. Further, the helix is 4-dimensional as the above diagram is the same in the x,z and y,z planes. (Re. imaginary time: note that the above helix can be generated using e^{ix} with x real. The value of x and the real and imaginary parts of e^{ix} provide the three real dimensions.) These helixes are suggestive as we will later consider an aggregate of venues (holding a mass) as being a helical distortion of space-time i.e. the wave function wave.

With two types of times, we also have two types of time reversal. Coordinate time reversal is the conventional notion: running the movie backwards. Reversal of sequence time, we argue, as it governs sequencing, results in the complementing of the space measures .

We now return to our preferred model of time as a complex dimension. (We do this because the Schrodinger wave equation's solutions are complex and we consider the waves as purely a distortion of space-time-matter. The wave equation must be complex (among other reasons) to assure that the free particle (complex) wave can have a constant probability density ($\Psi^*\Psi$).

We'll consider the sequencer function to be described by the imaginary (rolled-up) component of time (the phase). We note that a rolled up (real) fifth dimension was postulated by Kaluza and Klein[KaluzaKlein] to bring electromagnetism into the metric tensor. We can show (Appendix 2) that we can optain the Kaluza result using a rolled up imaginary fourth dimension.

The imaginary component acts much like a separate (time-like) fifth dimension. This is vaguely similar to the idea that there is a fifth dimension which *is* mass, as proposed by Mashhoon & Wesson[Mashoon] and the Space-Time-Matter consortium [SpaceTimeMatter].

We define Total (complex) time T.

T=τ+iυ.

τ is the 'Time Leaves no Tracks' version of t.

υ is the imaginary component of time. It is rolled-up at the Planck scale so in the macroworld T is indistinguishable from τ.

(Note: 'complex time' is not an entirely new idea, e.g. S. Hawking[Hawking].)

A property of time is that it (usually) advances. As υ is a component of time, we assume it advances as well. But υ is rolled-up, so, as it continuously advances, it continuously reaches a maximum and rolls over to zero. We represent this as a frequency.

Masreliez[Masreliez] and Mukhopadhyay[Mukhopadhyay] among others have suggested that a mass oscillates at its Compton frequency, (and without such oscillation, there would be no DeBroglie wave, or indeed a Ψ). We accept that suggestion. The Compton frequency ,f_c, is defined as $f_c = \frac{mc^2}{h} Hz$.

We first convert Hz to cycles/Planck time.

$\frac{f_c}{\sqrt{\frac{hG}{c^5}}} = \frac{mc^2}{h}$

Now we'll convert m from kilograms to Planck mass, m_p.

$\frac{f_c}{\sqrt{\frac{hG}{c^5}}} = \frac{mc^2}{h}\sqrt{\frac{hc}{G}}$

Simplifying, we have $f_c = m_p$.

This says that if the mass in a venue is zero, (from the viewpoint of the laboratory observer) the υ time does not advance. The more mass in a venue, the more 'rapidly' υ advances until at a maximum venue mass of one Planck mass, the frequency has increased to one cycle per Planck time. And in that latter case, every Planck time advances υ to the same angular point, which is then indistinguishable from a frequency of zero. In short then, we associate mass with a frequency (the Compton frequency) of the imaginary time component.

We consider now, a space-time occupied by a single (indivisible, a quark perhaps) mass.

As a trial idea, suppose a venue with mass migrates in all directions including time, i.e. it also migrates in (sequence) time.

Time on average moves forward for one Planck time, and then on average backward for one Planck time, etc. The average wavelength then, is $2t_p$seconds and the frequency f is $1/(2t_p)$ Hz.

The Compton frequency (f_c) is defined as $f_c = \frac{mc^2}{h}$. Equating the two frequencies gives,

$1 = \frac{1}{m}(\frac{h}{2c^2 t_p})$.

But the above is for only one space dimension. If we consider three space dimensions, then whenever an angle migration is due to occur, three migrations must happen (one for each angle axis). They can't happen at the same time as the rotation group is non-commutative.So in the above equation we must replace the above with,

$3 = \frac{1}{m}(\frac{h}{6c^2 t_p})$.

Substituting for h, c, and t_p yields $m \cong 2.43 * 10^{-8} kg$.

This is a remarkable result as the mass is very close to the Planck mass.

Instead of 1 or 3 above, we now ask the value for exactly one Planck mass, and substitute,

$t_p \equiv \sqrt{\frac{hG}{2\pi c^5}}$, and $m_p \equiv \sqrt{\frac{hc}{2\pi G}}$ where G is the constant of gravitation, we obtain,

$\pi/3 \approx$1.047, a value slightly greater than unity. Perhaps then, we should use the Planck pi, π_p, rather than π. And since π_p= 3, that gives a value of exactly one.

This is a nice result as it suggests:

1-the Planck length is the smallest possible length,

2-the Planck time is the smallest possible time, and

3-the Planck mass is the smallest possible classical mass (i.e. not subject to quantum mechanics).

In contrast to conventional QM where a massive particle has a wave function this model predicts that there isn't a wave function for a sufficiently large, mass. So, even in principle, the two slit experiment cannot be done with marbles, or cannonballs.

As to $\Psi^*\Psi$ We can still consider a probability curve but we'll interpret it differently: If we take any (horizontal) time (τ) as a 'now', A venue (containing a mass) stochastically flits forward and back in space-time. So that at 'now' there is one and only one particle. But where it is cannot be predicted. However, the likelihood of the particle being at a particular x (+/- dx) position is determined by the relative number of times the particle is at that position. This is analogous to $\Psi^*\Psi$. But the probability curve is a construct. It represents, but is not actually, the particle. When the particle is measured by, for example, being absorbed in a detector, it freezes (no longer moves stochastically). It no longer flits through time and space so the graph 'collapses' to the measured position. (that position is only determinable by the measurement.) This is analogous to the collapse of the wave function, but here there is no collapse problem. A previous paper [Frederick 3]noted that probability is observer dependent, and that applies to $\Psi^*\Psi$ as well.

There are a few points/speculations to be made about measurements. First, to be a true measurement, there must be a latch/flip-flop/memory so that the 'film' cannot be run backwards. As an example, consider the two slit experiment with electrons. If a measurement device is placed at a slit, there is no interference pattern. But when an electron goes through a slit, the orbital electrons in atoms of the wall of the slit will be distorted by the passage of the electron. This distortion is *almost* a measurement. But when the electron passes through the slit, the orbital electrons become un-distorted. The interference pattern is still produced because there is no latching of measurement information. A latch could be some mechanical contrivance, or even human (or non-human) memory. A fruit-fly observing at the slit will kill the interference pattern, but only for the fruit-fly. We think the process should be transitive; A human observing the fruit-fly's memory will cause the interference to be killed for the human as well. A measurement forges a connection between the thing being measured and the measurer–forcing them to have the same relative now. In the macro-world, virtually everything observes (via photons) everything else, forcing that macro-world (or a portion thereof) to have the same relative now. And measurements forces time to have tracks. Not that time is frozen, but looking back to a particular time will show uniquely what the world looked like at that time. E.g., if one were to do high-speed filming of particle 'tracks' in a cloud chamber, one would see the time-tracks.

Observation, a crucial part of a measurement, is conducted via photons. We speculate that *all* measurements are via photons.

The time leaves no tracks concept implies that there are multiple futures, and they all 'happen'. (This is somewhat redolent of the Everett many-world interpretation[Everett]) In Stochastic Granular Spave-time theory, an observation from the laboratory will select a particular future (making a track).

Let's consider the idea of the 'world-line'. Moving forward from the present, we are predicting the future. And with quantum uncertainties (as well as with the intervention of outside forces) that future cannot be predicted according to classical determinism. And if there is no completely deterministic trajectory going forward, then arguably neither is there one going backward in time. The world-line then, seems to have limited utility in quantum mechanics. Instead of a world-line, we consider a 'world-double-cone', with its apex at 'now' that widens as one moves forward or backward in time. So while quantum mechanics lets us probabilistically predict the future it also lets us probabilistically predict the past.

(Brief) Discussion

Stochastic Granular Space-time is neither String Theory nor Loop Quantum Gravity but is concerned with aspects common to both. In particular the nature of time is a thread running through the three theories. This paper is concerned mainly with time.

In order that we treat time in the same way as we treat space (and not to have particles appear at different places at the same time), we needed a new interpretation of time: 'Time Leaves No Tracks', complex time with the imaginary component 'rolled-up' at the Planck scale, and a very slow breaking of the symmetry of time (the arrow of time), and possibly a connection between mass and time (suggested by the Schwartschild solution). The implication is that our usual notion of time is just a human construct, not actually intrinsic to space-time.

Appendix 1: The Postulates of Stochastic Space-time

A (much) earlier paper[Frederick 1] posited a stochastic space-time. From the five statements (postulates) in that paper, the uncertainty principle, interference and the spread of a free particle were derived. The statements (described in detail in the earlier paper) are as follows:

Statement 1. A Mach-like principle.

1.1. In the absence of mass, space-time becomes not flat, but stochastic.

1.2. The stochasticity is manifested in a stochastic metric $g_{\mu\nu}$.

1.3. The mass distribution determines not only the space-time geometry, but also the space-time stochasticity.

1.4. The more mass in the space-time, the less stochastic the space-time becomes.

Statement 2, the contravariant observable theorem.

All measurements of dynamical variables correspond to contravariant components of tensors.

Note that when one makes an observation of a dynamical variable (e.g. position, momentum, etc.), the measurement is usually in the form of a reading of a meter (or meter-stick). It is only through a series of calculations that one can reduce the datum to, say, a displacement in a coordinate system. For this reduction to actually represent a measurement (in the sense of Margenau) it must satisfy two requirements. It must be instantaneously repeatable with the same results, and it must be a quantity which can be used in expressions to derive physical results (i.e., it must be a physically "useful" quantity). It has been shown[Frederick 4] that for Minkowski space, the derived "useful" quantity is contravariant.

Statement 3. The metric probability postulate.

$P(x,t) = f(-g)$, where for a one particle system is the particle probability distribution. f is a real-valued function and g is the determinant of the metric tensor.

In the earlier paper, $P(x,t) = f(-\sqrt{g})$,but further analysis implied the current probability distribution $[P(x,t) = f(g)]$. The arguments are as follows:

$P(x,t) = f(-g)$ can be justified by the following: Consider that there is given a sandy beach with one black grain among the white grains on the beach. If a number of observers on the beach had buckets of various sizes, and each of the observers filled one bucket with sand, one could ask the following: What is the probability that a particular bucket contained the black grain? The probability would be proportional to the volume of the bucket.

Consider now the invariant volume element dV_I in Riemann geometry. One has that[Weber]

$dV_I = \sqrt{-|g|}dx^1dx^2dx^3dx^4$.

It seems reasonable then, to take $\sqrt{-|g|}$ as proportional to the probability density $(\Psi^*\Psi)$ for free space.

Consider again, the sandy beach. Let the black grain of sand be dropped onto the beach by an aircraft as it flies over the center of the beach. Now the location of the grain is not random. The probability of finding the grain increases as one proceeds toward the center, so that in addition to the volume of the bucket there is also a term in the probability function which depends on the distance to the beach center. In general then, we would expect the probability function $P(x,t)$ to be $P(x,t) = A\sqrt{-|g|}$ where A is a function whose value is proportional to the distance from the center of the beach.

(From here on, we'll represent the determinant of $g_{\mu\nu}$ by g rather then by $|g|$.)

The arguments above apply to the three-dimensional volume element. But we left out the other determinant of the probability density, the speed of the particle (the faster the particle moves in a venue, the less likely it is to be there.) And therefore, the larger the Δt the more likely the particle is to be found in the venue. So indeed (it seems as if) it is the four-dimensional volume element that should be used.

The metric probability statement $P(x,t) = A\sqrt{-g}$, as it stands, has additional problems:

First, if one considers the 'particle in a box' solution, one has places in the box where the particle has zero probability of being. And if $P(x,t) = A\sqrt{-g}= 0$, that means the determinant of the metric tensor is zero and there is a space-time singularity at that point. We address this problem by noting that the metric tensor is composed of the average, non-stochastic, background (Machian) metric $g^M_{\mu\nu}$ and the metric due to the Particle itself $g^P_{\mu\nu}$. We say then that the probability density is actually $P(x,t) = A(\sqrt{-g^T} - \sqrt{-g^M})$ where g^T is the determinant of the composite metric. In this case, $P(x,t)$ can be zero without either $g^T_{\mu\nu}$ or $g^P_{\mu\nu}$ being singular.

A second and more trenchant problem is that $P(x,t) = A\sqrt{-g}$ describes the probability density for a test particle placed in a space-time with a given (average) metric due to a mass, with determinant g. What we want, however, is the probability of the particle (not the test-particle) due to the metric contribution of the particle itself. Related to this is that $P(x,t) = A\sqrt{-g}$ doesn't seem to replicate the probability distributions in quantum mechanics in that the probability distribution, $\Psi^*\Psi$, is the square of a quantity (assuring that the distribution is always positive). But the differential volume element, $dV = \sqrt{-g}$ $dxdydzdt$ is not the square of any obvious quantity. Further, $P(x,t) = A\sqrt{-g}$ is something of a dead end, as it gives $\Psi^*\Psi$ but no hint of what Ψ itself might represent. It would be nice if the probability density were proportional to the square of the volume element rather than to the volume element itself. With that in mind we'll again look at the probability density.

There is another argument, but it assumes the model of time in Section IV (relating to a time-like fifth dimension we have called tau).

Consider a quantum particle at a τ-time slice at, say, τ=now. And also consider a static quantum probability function (e.g. a particle in a well) at τ=now+1. (That function is a result of the quantum particle's migrations in time and space,) Then if we take a negligible mass test particle at τ=now, it will have a probability of being found at a particular location at τ=now+1 equal to that static probability function. And that function is proportional to the volume element (the square root of minus the determinant of the metric tensor). But what we're interested in is general the probability function of the quantum particle as τ goes from now to now+1. We are considering the probability function at τ+1 as static. But it is the result of the migrations of the particle. At tau=now, it would then be the same probability function. So, as we go from now to now plus one, we would need to multiply the two (equal) probability functions. This results in the function being proportional to the determinant of the metric tensor (not its square root). This is rather nice as it allows us to suggest that the volume element is proportional to Ψ while the probability density is proportional to $\Psi^*\Psi$. Note that this result is due to a mass interacting with the gravitational field it itself has generated. (This is analogous to the quantum field theory case of a charge interacting with the electromagnetic field it itself has created.)

As yet another approach, consider the spread of probability due to the migration of venues. In the absence of a potential, the spread (due to Brownian-like motion) will be a binomial distribution in space (think of it at the moment, in a single dimension and time). But there is also the same binomial distribution in time. This, for example, expresses that the distant wings of the space distribution require a lot of time to get to them. The distribution then seems to require that we multiply the space distribution by the time distribution. The two distributions are the same so the result is the square of the binomial distribution. (The argument can be extended to the three spacial dimensions.) In the laboratory frame, time advances smoothly, which is to say that the time probability density distribution is a constant, so we do not get the square of the binomial distribution..

It seems then that there are both the distribution and its square in play. It might be that the covariant representation, i.e. the distribution 'at' the particle, is the binomial while a distant observer, where time advances smoothly (not in the quantum system being observed), observes (i.e contravariant measurements) the square of the binomial distribution.

Note: As the probability density is not stochastic while the metric components are, that puts constraints on the metric tensor, i.e. the determinant of the metric tensor is constant while the metric components are not. So (stochastic) changes in one or more components are compensated by opposite changes in the others. This implies that while a venue is in constant flux, its dimensions continuously and unpredictably change while the venue maintains a constant volume. This also implies that the metric stochasticity is due to a single (and the same) random variable in each non-zero metric component (That variable will then drop out in the determinant.)

Note that while the metric tensor, $g_{\mu\nu}$ is stochastic,$|\ g_{\mu\nu}\ |$ is not. What metric property can be preserved (to provide that exact non-stochasticity)? We suggest for a diagonal metric tensor, it is the line element, ds^2. So that for every space migration (forward or back) of one Planck length, there is a time migration (forward or back). of one Planck time. (E.g. with such a diagonal metric, it is easy to see that that determinant is non-stochastic.) In general then, we suggest that the stochasticity of the metric is counteracted by variations of elements of the metric being the reverse of other elements.

A note on the holometer experiment[**?**]: The experiment looks for space-time fluctuations at the Planck scale, and has found no fluctuations. (The experimenters though, suggested that perhaps some unknown symmetry masks fluctuations.) The quantum zero point energy uncertainty however, says that there are energy fluctuations which are equivalent to mass fluctuations which (from general relativity) generate stochastic metric tensor fluctuations. We (among others) identify the space-time volume element as proportional to the quantum mechanical probability density which is not stochastic. The volume element is the determinant of the metric tensor. Again we have then, a stochastic metric tensor and a non-stochastic determinant of the metric tensor. This could happen if for any fluctuation of a metric tensor component, other components reverse the fluctuation. In the case of a local diagonal metric, the fluctuations of the space components could be counteracted by the time component. This could be that aforementioned unknown symmetry. We suggest then, that the null result of the holometer experiment supports our granular stochastic space-time model. (Craig Hogan, who came up with the Fermilab holometer experiment concurs (personal communication) that the metric model above could indeed possibly explain the holometer negative results.)

Statement 4. the metric superposition postulate.

If at the position of a particle the metric due to a specific physical situation is $g_{\mu\nu}(1)$ and the metric due to a different physical situation is $g_{\mu\nu}(2)$ then the metric at the position of the particle due to the presence of both of the physical situations is $g_{\mu\nu}(3)$,

$g_{\mu\nu}(3) = \frac{1}{2}[g_{\mu\nu}(1) + g_{\mu\nu}(2)]$.

This is the case where the probabilities, $P_1$and P_2, of the two metrics are the same. In general though, Statement 4 becomes,

$g_{\mu\nu}(3) = P_1 g_{\mu\nu}(1) + P_2 g_{\mu\nu}(2)$.

Statement 5. The metric Ψ postulate.

There exists a local complex diagonal coordinate system in which a component of the metric at the location of the particle is the wave function Ψ.

Appendix 2: Kaluza-Klein in Four Dimensions with Complex Time

About a century ago, Theodor Kaluza proposed adding a fifth-dimension in order to bring the magnetic vector into geometry. So that the dimension not affect observable geometry, the fifth dimension was assumed to be 'rolled up' at the Planck scale. This feature, the 'cylinder condition', says to drop all derivatives with respect to the fifth dimension coordinate.

The Kaluza Metric Tensor (which we'll refer to as KMT) is,

$$\text{KMT}\equiv\left\{\begin{array}{ccccc} g_{00} & g_{01} & g_{02} & g_{03} & A_0 \\ g_{10} & g_{11} & g_{12} & g_{13} & A_1 \\ g_{20} & g_{21} & g_{22} & g_{23} & A_2 \\ g_{30} & g_{31} & g_{32} & g_{33} & A_3 \\ A_0 & A_1 & A_2 & A_3 & 1 \end{array}\right\}$$

where A_0, A_1, A_2, and A_3 are the components of the electromagnetic 4-potential.

The KMT has five additional variables. But one of those variables, g_{44}, is problematic; It's often taken to be superfluous and set equal to one.

We'll call the fifth-dimension 'w'

The line element $\equiv g_{AB}dx^A dx^B$ (where as per convention, Roman letters range from zero through four).

The Kaluza Line Element (KLE) then, is,

KLE$\equiv g_{00}dt^2+2g_{01}dtdx+2g_{02}dtdy+2g_{03}dtdz+2A_0dtdw+g_{11}dx^2+2g_{12}dxdy+2g_{13}dxdz+2A_1dxdw+g_{22}dy^2+2g_{23}dydz+2A_2dydw+g_{33}dz^2+2A_3dzdw+dw^2$

w is the Kaluza fifth-dimension. It is 'rolled up'.

The Four-dimensional Metric Tensor with complex time (which we'll refer to as FMT) is,

$$\text{FMT}\equiv\left\{\begin{array}{cccc} g_{00}+i\alpha_0 & g_{01}+i\alpha_1 & g_{02}+i\alpha_2 & g_{03}+i\alpha_3 \\ g_{10}+i\alpha_1 & g_{11} & g_{12} & g_{13} \\ g_{20}+i\alpha_2 & g_{21} & g_{22} & g_{23} \\ g_{30}+i\alpha_3 & g_{31} & g_{32} & g_{33} \end{array}\right\}$$

where $\alpha_0, \alpha_1, \alpha_2, and, \alpha_3$ are quantities which we will show to be identifiable with the electromagnetic 4-potential (A_0,A_1,A_2,A_3).

Analogously to the KLE, the Four-dimensional Line Element (FLE) is,

FLE$\equiv g_{00}dt_c^2+i\alpha_0dt_c^2+2g_{01}dt_cdx+2i\alpha_1dt_cdx+2g_{02}dt_cdy+2i\alpha_2dt_cdy+2g_{03}dt_cdz+2i\alpha_3dt_cdz+g_{11}dx^2+2g_{12}dxdy+2g_{13}dxdz+g_{22}dy^2+2g_{23}dydz+g_{33}dz^2$

where t_c represents complex time; $t_c = t_r + it_i$ where t_r and t_i represent real and imaginary time respectively, and the αs are a yet to determined function of the As.

Now replacing dt_c with $dt_r + idt_i$ and expanding, and noting that t_r is equivalent to KLE's t, (so in FLE, we will replace t_r with t.

$FLE = g_{00}dt^2 - g_{00}dt_i^2 + 2ig_{00}dtdt_i + i\alpha_0dt^2 - i\alpha_0dt_i^2 - 2\alpha_0dtdt_i + 2g_{01}dtdx + 2ig_{01}dt_idx + 2i\alpha_1dtdx - 2\alpha_1dt_idx + 2g_{02}dtdy + 2ig_{02}dt_idy + 2i\alpha_2dtdy - 2\alpha_2dt_idy + 2g_{03}dtdz + 2ig_{03}dt_idz + 2i\alpha_3dtdz - 2\alpha_3dt_idz + g_{11}dx^2 + 2g_{12}dxdy + 2g_{13}dxdz + g_{22}dy^2 + 2g_{23}dydz + g_{33}dz^2$

t_i is the four-dimensional metric imaginary component of time. It is, like w in the KLE, also 'rolled up'.

Hawking<CITE> has said that the imaginary time component is orthogonal to the real time component, and therefore acts as if it were a space coordinate. Accordingly, we are justified in associating it_i with w. (I.e. $t_i = -iw$)

$FLE = g_{00}dt^2 + g_{00}dw^2 + 2g_{00}dtdw + i\alpha_0dt^2 + i\alpha_0dw^2 + 2i\alpha_0dtdw + 2g_{01}dtdx + 2g_{01}dwdx + 2i\alpha_1dtdx + 2i\alpha_1dwdx + 2g_{02}dtdy + 2g_{02}dwdy + 2i\alpha_2dtdy + 2i\alpha_2dwdy + 2g_{03}dtdz + 2g_{03}dwdz + 2i\alpha_3dtdz + 2i\alpha_3dwdz + g_{11}dx^2 + 2g_{12}dxdy + 2g_{13}dxdz + g_{22}dy^2 + 2g_{23}dydz + g_{33}dz^2$

Now we'll collect real and imaginary terms,

$FLE = g_{00}dt^2+g_{00}dw^2+2g_{00}dtdw+2g_{01}dtdx+2g_{01}dwdx+2g_{02}dtdy+2g_{02}dwdy+2g_{03}dtdz+2g_{03}dwdz+g_{11}dx^2 + 2g_{12}dxdy + 2g_{13}dxdz + g_{22}dy^2 + 2g_{23}dydz + g_{33}dz^2 + i(\alpha_0dt^2 + \alpha_0dw^2 + 2\alpha_0dtdw + 2\alpha_1dtdx + 2\alpha_1dwdx + 2\alpha_2dtdy + 2\alpha_2dwdy + 2\alpha_3dtdz + 2\alpha_3dwdz)$

The line element, $ds^2 = g_{AB}dx^A dx^b$, must be real, so the imaginary components must sum to zero:

$i(\alpha_0 dt^2 + \alpha_0 dw^2 + 2\alpha_0 dtdw + 2\alpha_1 dtdx + 2\alpha_1 dwdx + 2\alpha_2 dtdy + 2\alpha_2 dwdy + 2\alpha_3 dtdz + 2\alpha_3 dwdz) = 0$

If the above is zero, then -i times the above is also zero. We can then replace the above by -i times the above in the FLE.

Multiplying the above by -i, and then factoring,

$\alpha_0(dt^2 + dw^2 + 2dtdw) + 2\alpha_1(dtdx + dwdx) + 2\alpha_2(dtdy + dwdy) + 2\alpha_3(dtdz + dwdz) = 0$

$\alpha_0(dt + dw)^2 + 2\alpha_1 dx(dt + dw) + 2\alpha_2 dy(dt + dw) + 2\alpha_3 dz(dt + dw) = 0$

Dividing by dt+dw,

$\alpha_0(dt + dw) + 2\alpha_1 dx + 2\alpha_2 dy + 2\alpha_3 dz = 0$, and multiplying by dw,

$\alpha_0(dt + dw)dw + 2\alpha_1 dxdw + 2\alpha_2 dydw + 2\alpha_3 dzdw = 0.$

t and w are both real time coordinates. It seems reasonable to take dt to be equal to dw so the above becomes,

$2\alpha_0 dtdw + 2\alpha_1 dxdw + 2\alpha_2 dydw + 2\alpha_3 dzdw = 0.$

Note now the KLE with terms containing A collected,

KLE$\equiv g_{00}dt^2 + 2g_{01}dtdx + 2g_{02}dtdy + 2g_{03}dtdz + g_{11}dx^2 + 2g_{12}dxdy + 2g_{13}dxdz + g_{22}dy^2 + 2g_{23}dydz + g_{33}dz^2 + dw^2 + (2A_0 dtdw + 2A_1 dxdw + 2A_2 dydw + 2A_3 dzdw)$

Notice now that the A terms in the KLE are identical to the α terms in the FLE. So we are justified in presuming that the FLE α terms are indeed the magnetic vector potential terms of the KLE. So then, the two line elements are equivalent. And that shows that we get the full Kaluza formalism in four (rather than five) dimensions, but with complex time. And again, note that the problematic g_{44} component of the Kaluza metric is absent in the FMT metric.

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