Stochastic space-time and quantum theory:
Part B: Granular space-time

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A previous publication in Phys. Rev. D, (Part A of this paper) pointed out that vacuum energy fluctuations implied mass fluctuations which implied curvature fluctuations which then implied fluctuations of the metric tensor. The metric fluctuations were then taken as fundamental and a stochastic space-time was theorized. A number of results from quantum mechanics were derived. This paper (Part B), in addressing some of the difficulties of Part A, required an extension of the model: In so far as the fluctuations are not *in* space-time but *of* space-time, a granular model was deemed necessary. For Lorentz invariance, the grains have constant 4-volume. Further, as we wish to treat time and space similarly, we propose fluctuations in time. In order that a particle not appear at different points in space at the same time, we find it necessary to introduce a new model for time where time as we know it is emergent from an analogous coordinate, tau-time, τ, where 'τ-Time Leaves No Tracks' (that is to say, in the sub-quantum domain, there is no 'history'). The model provides a 'meaning' of curvature as well as a (loose) derivation of the Schwartzschild metric without need for the General Relativity field equations.

The purpose is to fold the seemingly incomprehensible behaviors of quantum mechanics into the (one hopes) less incomprehensible properties of space-time.

I. INTRODUCTION

Although it is a remarkably reliable schema for describing phenomena in the small, quantum mechanics has conceptual problems; e.g. How can entanglement send information faster than light (without violating relativity)? What is happening in the two-slit experiment? How can it be that the wave function can instantaneously collapse? In what medium does the Ψ wave travel? Is the E=hf wave (the Compton wave) the same as the Ψ wave? What is the wave function? What explains superposition? Can the two-slit experiment (at least in theory) be performed with macroscopic masses? Is 'The Cat' alive or dead? (One should say at the outset that this stochastic space-time theory is a DeBroglie-Bohm rather than a Copenhagen model so Schrödinger's cat is not an issue; Waves interfere. Particles do not.)

The mathematics of quantum mechanics works exceedingly well. What we attempt in this paper (in a continuation of the previous Part A[1] and an updated version[2]) is to provide a conceptual framework for the quantum phenomena described by the mathematical formalism. Addressing logical problems in Part-A required introducing a granular model for space-time and also a re-interpretation of the concept of time in the quantum domain.

Granular space-time theories often suffer from the problem that if the grains have a specific size, then the theory cannot be Lorentz invariant. Our grains though (which we call 'venues' to distinguish them from point-like 'events'), have constant 4-volumes (rather than constant dimensions) and 4-volumes *are* Lorentz invariant. In empty space, with venues in a (average) rest frame, the venues have dimensions of Planck length times Planck length times Planck length times Planck time times c. And the stochasticity is exhibited by venues migrating in discrete intervals of one Planck length. We required granularity since the (stochastic) space-time must tessellate the manifold. But point-like events have no volume which is to say that multiple events can migrate to the same 'point' in the manifold.

Another problem is stochasticity in time. For covariance one would like to treat time and space similarly. To do that, we then let the stochasticity apply to both space and time. This leads to an obvious problem: If a venue contains mass, then migrations can position the mass so it appears at multiple positions in space at the same time. E.g. A venue containing mass could migrate one unit backward in time, then one unit forward in, say, x, then one unit forward in time, resulting in the mass being at both (x,y,z,t) and (x+1,y,z,t). Preventing this necessitates a change in how we view time.

First, 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 certain. And if there is no completely deterministic trajectory going forward, 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-tube', the diameter of which increases as one moves forward or backward from the present.

We suggest that for the quantum world, t is not the forth dimension, and that t is an emergent quantity, if not merely a human construct. t is a defined quantity in the laboratory frame whereas we suggest (below) another quantity, τ (tau-time) is appropriate in the quantum domain.

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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, in the section on 'Migrations in Space and Time', τ will be seen to provide a solution to the collapse of the wave-function problem.

The approach taken here considers a granular space-time undergoing Brownian Motion in both space and time. A Wiener Process is our starting point in modeling a granular, indeterminate space-time.

II. WIENER (AND WIENER-LIKE) PROCESSES

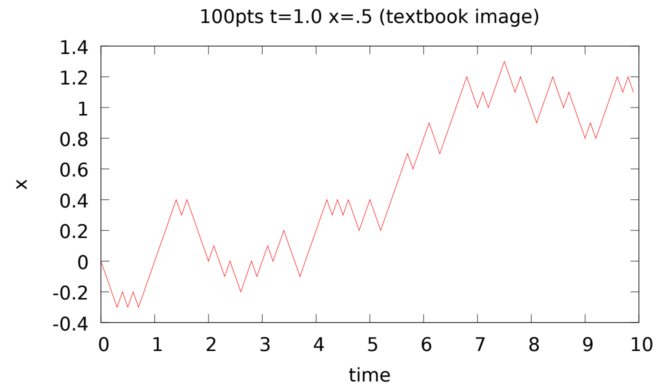
First, we consider Wiener migrations in space.

A Wiener Process W is an idealization of Brownian motion. It is a random walk of n steps where n approaches infinity. (But, as we regard venues not to be point-like but granular, we will not be taking the process to infinity.)

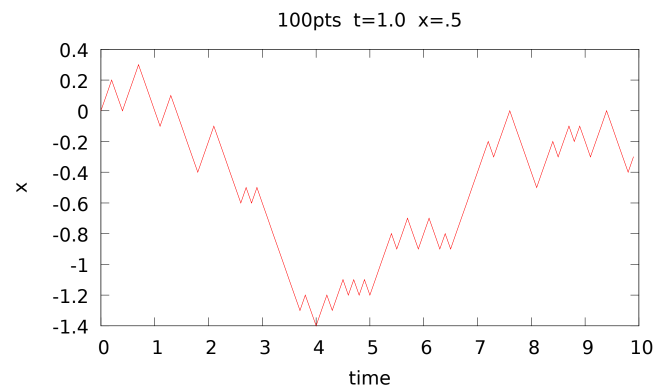
The ith step is defined as

$W_i = W_i - 1 + \frac{X}{\sqrt{i}}$

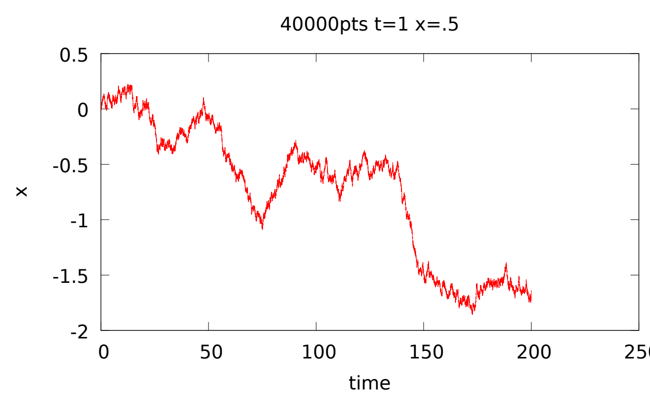
where X is a binary random variable (+ or - 1). As n gets large, the distribution of W_i tends towards the unit normal distribution. As can readily be seen, as i goes to infinity, the W graph is everywhere continuous but nowhere differentiable. The graph is fractal (in that it is scale independent). The graph is a 'space filling' curve with fractal dimension 1.5. Traversing between any two points along the curve requires covering an infinite distance. However, in any finite time interval, there are found all finite values of x. So in the case where a venue can move, it can move to all values of x in an arbitrarily small time interval (e.g. faster than light).



Here is something of a textbook example of a 100 point Wiener Process curve with measure=0.5. Note: 'measure' refers to the probability of a 'coin flip' being heads. E.g. a measure of 0.75 means there is a 75% probability of the coin being heads (or left vs. right, or up vs, down).

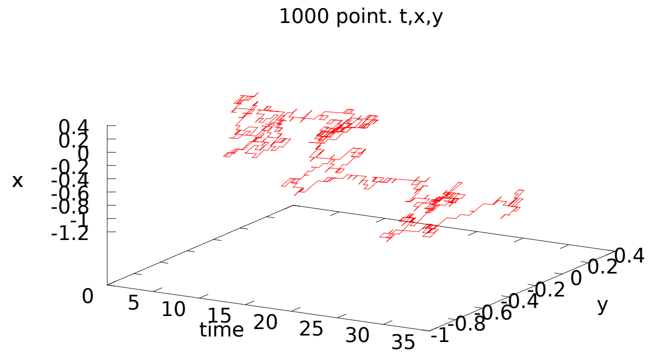


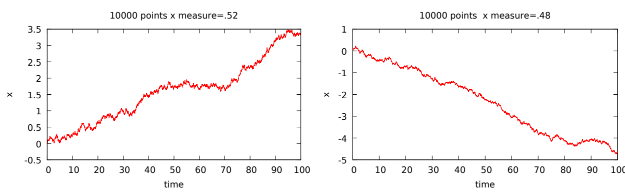
And here is another example (differing in the sequence of [pseudo]random numbers). Although the two curves look different, they are fundamentally the same (100 points, 0.5 measure).



And above is a 40000 point example.

Extended to infinity, the variable i becomes a continuous variable, generally represented as t (time). The above is for a 2-dimensional process (t vs x). To extend that to t, x and y, two coins are flipped, one for x migration and the other for y.



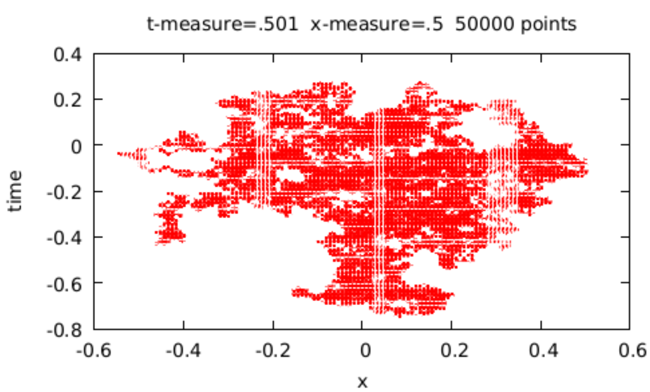


An x measure greater than .5 causes a tendency to drift up. Less than .5 tends downward

III. MIGRATIONS IN BOTH SPACE AND TIME; TIME IN QUANTUM MECHANICS; WORLD-TUBES

For reasons of covariance, we would like to treat time and space similarly. And so we will consider diffusion in space as well as in time.

Consider Graph 'A' (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 with a measure of 0.5, and also for a migration in t where the measure of t is 0.501 (meaning that t will slightly tend upward). We can regard the graph as showing migration in x and also t, where the coordinate axes are laboratory x and laboratory t.



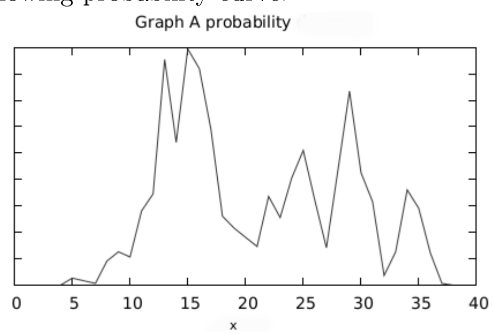
Graph 'A'

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.

This problem has been addressed (in the introduction) by introducing τ (tau-time), and the 'τ-Time Leaves no Tracks' idea.

We can still consider Graph 'A', 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 time and space. 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. In the case of Graph 'A', if we take as 'now' the τ-time slice at -0.2, for example, we find (by examining the data) the following probability curve:



This is analogous to $\Psi^*\Psi$. But the graph is a construct. It represents, but is not actually, the particle. When the particle is measured, 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 (as the graph was merely a mathematical construct) there is no collapse problem. Again, the particle has always existed at only a single venue, but the venue migrations happen roughly at the rate of the Planck time, making the particle appear (in some sense) to be at multiple positions at a particular time. Further, (because of the properties of Wiener Processes) the particle *appears* to spread.

Note: The jagged lines in the graph (as opposed to a smooth curve) is an artifact of the binning algorithm in the software.

By Statement 1.4, the particle location becomes less stochastic as mass increases. There is a point where the stochasticity ceases. At that point, (since it is not migrating back and forth through τ-time), one can use the usual t-time. So, we consider t-time (and also causality) to be an emergent quantity. In the rest of this paper, when we do not reference history, we will simply use t instead of τ.

Now we can (briefly) revisit Statement 3: The metric probability postulate, $P(x,t) = -kg$. A particle, by its mass, generates a local contribution to the metric tensor at the observer's 'now'. The particle will flit forward or backward in time. The local metric contribution, being an extended field, will not flit with it, and, for the same reason, will not instantaneously decay. When the particle flits back to the observer's now, it will be subject to that extended metric field. (This is somewhat akin to quantum field theory where a particle interacts with the electromagnetic field created by its own charge. Here, the particle interacts with the gravitational field created by its own mass.) So $P(x,t) = -kg$. can fully apply.

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 a venue is in constant flux, its dimensions continuously and unpredictably changing 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.)

IV. VENUE MIGRATIONS IN EMPTY SPACE

Mach's Principle posits that the local properties of space-time depend on the mass distribution in the universe. We'll adapt the principle to our model. And we'll introduce another variable: 'Indeterminacy', the probability that migrations will actually happen. Indeterminacy then, is likely related to the concept of inertia.

As with Measure, indeterminacy is implemented with a 'coin flip'. And we'll suggest that outside of a mass, the indeterminacy decreases with decreasing distance from the mass/energy (i.e. space becomes more determinate as one approaches a mass). It will be seen that Measure mainly influences quantum effects while Indeterminacy influences relativistic effects.

The space-time Indeterminacy decreases as one approaches a mass. But this is underspecified; masses can have different densities, so we wouldn't expect the Indeterminacy to necessarily vanish at the surface of a mass. Yet we do not want masses to be pulled apart by the space-time so we'll say that migrations cease at the surface of a mass. But venues can still migrate away from the surface.

We'd expect that at some distance, Rs, from the center of the mass, the venues, if they could migrate to there, would be trapped, i.e. unable to migrate away. And if Rs were outside the mass radius, the venues could migrate to Rs where they would be trapped. This is highly suggestive of the event horizon of the Schwarzschild solution. We'll assume Rs (the Indeterminacy radius) and the Schwartzschild radius are the same.

The concept of Indeterminacy decreasing with closeness to mass has an interesting consequence relating to measurement: A measurement requires an exchange of energy between what is being measured and the measurer (an energy that can't be transformed away). But energy of this form (e.g. photons), being equivalent to mass, forces determinacy.

So, for example, if one were to place a measuring apparatus at one slit in the two-slit experiment, activity at that slit (at the time it is measuring if a particle went through it) would be deterministic (because the measurement, via of photons, forces determinacy). And therefore, the interference pattern would not happen.

Insofar as measurements are accompanied by exchanges of photons, it's tempting to consider that photons are the carriers of causality.

Up to this point, we've considered the migration of just a single venue. The model though, assumes space-time is completely 'tiled' by venues, i.e. there are no regions of space-time that are not fully covered by venues. While we can justify the migration of a single venue, migrations of venues in a completely tiled space-time is more problematic, especially as the space-time is subject to dynamic, indeterminate curvature fluctuations (due to the vacuum energy fluctuations). One might even doubt that there can be any migrations at all in a fully-tiled space-time. We are modeling the stochasticity of space-time as a Wiener-like process on venues (grains). We assume that the space-time completely tessellates the space-time (i.e. there are no holes in the space-time). How then can migrations occur in a fully tiled space-time?

The migration can proceed in one or two ways: The first is like the circulation in a perfect fluid. The 'diffusion' in that case, is via closed loops in the space-time.

The second way is the squishing-interchange of venues, as shown below: The diagrams represent an idealized pair of venues. The black and white venues continuously move to interchange their positions while keeping their volumes constant.

While our model is of a discrete, granular space-time, the discreetness is expressed in the venue volumes. So local continuous processes (between adjacent venues) as the above are not disallowed.

The migration problem persists though, as can be seen in Indeterminacy: Assume a spherical mass in an otherwise empty space. Indeterminacy is assumed to decrease as a venue migrates towards a mass. Even with Measures = 0.5, a venue will at some point approach arbitrarily close to the mass. But (letting R be the radial distance to the mass) as Indeterminacy is the probability that the venue will not migrate at the next coin flip, the venue will spend increasing amounts of 'time' as R decreases. In the case of multiple venues, there will be proportionally more of them in a volume element closer to the mass. This results in the 'piling up' of venues as one gets closer to the mass. How can this be? We don't want to resort to venues 'pushing' against other venues since that would imply that the venues are overlaid onto space-time instead of them being space-time. Nor do we (yet) want to employ higher dimensions. An answer (perhaps the only answer) is curvature. But what is curvature? 't Hooft has theorized[3] that curvature is an artifact of the fact that we live in four dimensions but space-time is actually five dimensional (e.g. a two dimensional being on a sphere can measure curvature, but with the sphere embedded in a flat three dimensions, there is no curvature.) We will take a different approach: Venues are assumed to have constant volume but not constant dimensions. Curvature will be described, below, as the thinning of space dimensions, while the time dimension thickens.

As for the translatory motion of the particle (as opposed to the rotational), the particle doesn't become 'fuzzy', but its location does begin to blur as the mass decreases below the Planck mass. This results in an effectively larger grain size.

Two effects: like a smaller pollen grain in Brownian motion: the smaller the grain, the more it stochastically moves. But as the effective grain radius increases, the movement decreases as there is a larger circumference over which the movements can average.

Note then that the effective radius *rate* of increase decreases as the effective radius increases. To reiterate, this is because, as the particle grows in *effective* size the average effect of the venue migrations against the particle surface begin to average out (analogous to the case of Brownian motion where the jitter of a large pollen grain is less than that of a smaller grain).

We maintain that all physics that uses the radius should use the effective radius. radius= rest-radius + *Radius Quantum Correction:* $r = r_{c+} r_{qc}$. For an example of the effective radius, see the Schwarzschild metric derivation below.

One might consider the 'actual' radius as the covariant (and hence unobservable radius) whereas the effective radius is the contravariant (in principle, observable) radius.

We explore now whether the model might indeed reproduce the Schwarzschild metric.

A mass generates curvature, that is to say, a deformation of venues. While to a distant observer the venues are deformed to be spatially concentrated around the mass, to the venues near the mass there is no observable evidence of such concentration as the space-time itself is 'deformed' (by way of the venues) so any 'observer' in a venue would be unaware of the deformation.

Consider space-time with a single spherical mass m with an Indeterminacy radius Rs. The Wiener graphs are for some undefined unit of time. But as one increases the number of coin flips towards infinity, the time interval decreases to an infinitesimal, dt. For a granular space-time though, the number of coin flips isn't infinite and the time interval, though small, isn't infinitesimal. Once again, Indeterminacy is the probability of, given that the venue is at a position with that Indeterminacy, the venue migrates from that position at the next coin flip.

Since migrations slow as venues approach a mass, indeterminacy then, expresses the slowdown in time and the compression of space as the venue approaches Rs. [As we'll be frequently employing Indeterminacy, we'll represent it by the letter 'u' (from the German word for indeterminacy, Unbestimmtheit)].

As a venue migrates in towards R_s, u decreases. The probability density of the venue being at a particular radial distance, r, therefore, increases. This results in venues piling up as they approach R_s. But as the venues 'tile' space-time, the only way they can pile up is by way of curvature (i.e. squishing in the radial dimension and compensating by lengthening in the time dimension): To a distant observer, the venues would decrease in size and migrate more slowly which is to say time would slow down.

Recalling (see Statement 2) that the contravariant distance to a lack hole is $\int_0^{\bar{r}} dr = \bar{r}$, while the covariant distance is $\int_0^{\bar{r}} d(\frac{r}{1-2Gm/r}) = \infty$, we can (in Cartesian coordinates) associate the contravariant distance with the number of *Planck lengths* from the observer to the point of observation and the covariant distance with the number of *venues* from the observer to the point of observation.

[This implies that local to the particle, space-time is not stochastic. And there, a deterministic Lagrangian can be defined. That 'local to the particle space-time' coordinate system is covariant (as it is moving with the particle). From another coordinate frame (e.g. the laboratory frame) measurements on that local frame are subject to the intervening stochasticity, and because of that stochasticity, the measurements are also stochastic, and the measurements are contravariant, as can be seen by the raising of the covariant coordinates by the stochastic metric tensor).]

Now, near r = R_s, space-time becomes Q-classical (no quantum effects, as opposed here to R-classical: no general relativity effects) so a metric makes some sense. Since the Measures (bias in the coin flips) are presumed not to be a function of location, we take the simplifying assumption that the metric tensor does not depend on the Measures, but only on the Indeterminacy, u. And, for the moment, we'll ignore how a venue migrates *in* a mass (when R_s is less than the mass radius).

Since for a mass, we have spherical symmetry, we can let, $ds^2 = -f(u)dt^2 + g(u)dr^2 + r^2 d\Omega^2$where f and g are two (to be determined) functions of u, and $d\Omega^2 \equiv d\theta^2 + sin^2(\theta) d\varphi^2$is the metric of a 2-dimensional sphere. Consider f(u) and g(u). We wish dt to lengthen and dr to shorten as u decreases. ds can be thought of as the time element in the frame of the venue. So, for example, as u goes to zero, a big change in t will result in a small change of s, and a small change in r results in a large change in s. The *simplest* implementation of the above suggests that $f(u)$ is just u itself and $g(u)$ is u^{-1}i.e. $ds^2 = -udt^2 + u^{-1}dr^2 + r^2 d\Omega^2$.

Now, as to u, note that,
at r = infinity: u = 1,
at r = Rs : u =0, and

for r < Rs : u can become unphysical (u<0).

The *simplest* expression for u satisfying the above is, $u = (1 - \frac{R_s}{r})$ which gives us

$ds^2 = -(1 - \frac{R_s}{r})dt^2 + (1 - \frac{R_s}{r})^{-1}dr^2 + r^2 d\Omega^2$

We have of course, as described earlier, equated the Schwartzschild radius with the Indeterminacy radius.

This is the result Karl Schwartzschild derived from the General Relativity field equations. One can easily go a bit further by noting that R_s can only be a function of the mass, and finding a product of mass with some physical constants to give a quantity with dimensions of length suggests $R_s = \frac{kGm}{c^2}$ where k is a constant. So we now have (setting units so that c=1),

$ds^2 = -(1 - \frac{kGm_s}{r})dt^2 + (1 - \frac{kGm_s}{r})^{-1}dr^2 + r^2 d\Omega^2$.

We still need to determine the value of the constant, k. But this is known territory. R_s was derived (by Schwarzschild and others) by requiring the metric to reproduce the Newtonian result at large values of r and small values of mass, and we need not reproduce the derivation(s) here.

At first glance, there appears to be a conflict between the Schwarzschild metric and stochastic granular space-time theory in that for masses less than the Planck mass, the Schwarzschild radius is less than the Planck length (which is not allowed as the Planck length is posited to be the minimum possible). But, as described earlier, any physical radius must be the *effective* radius (effective radius= rest-radius + Radius Quantum Correction). As a mass decreases to below the Planck mass, quantum effects occur which increase the effective radius. So a Schwarzschild radius of one Planck length is the minimum possible Schwarzschild radius. Masses less than one mass then increases the (effective) Schwarzschild radius (until the rate of increase decreases to zero). That the Schwarzschild radius of a Planck mass is the Planck length is then consistent with the granular hypothesis.

V. STOCHASTIC GRANULAR SPACE-TIME AND THE LORENTZ AETHER THEORY

We consider that our Stochastic Granular Space-time (SGS) theory is (or can be made to be) a super-set of the Lorentz Aether Theory (LAT) where the aether is space-time itself (specifically, the 'grains'/venues making up the space-time). By doing so, we can appropriate the LAT derivation of the constancy of the speed of light. (We feel that any theory of space-time should contain an explanation of that constancy.)

As is widely known[4], the Michelson-Morley experiment failed to find the Lorentz aether, thus seemingly invalidating the Lorentz Theory[5]. Less widely known perhaps, is that the second version of Lorentz's theory (with H. Poincairé as second author) reproduced Einstein's Special Relativity (ESR) so well that there is no experimental way to decide between the two theories[6]. The second LAT theory differs from the first in that it posits that the aether is partially dragged along with a moving body in the aether. This is akin to frame dragging (e.g. the Lense-Thirring effect) in the Kerr Metric[7]. We will posit frame dragging in SGS as well, i.e. the dragging along of venues by a moving object. (Note that the Kerr metric itself 'breaks' the continuity space-time. If it didn't, the frame dragging would 'wind-up' space-time, and it doesn't[8]. One might take this as an argument for a discrete space-time such as in SGS.)

Although LAT derives the constancy of the speed of light whereas ESR takes it as a given, there are objections to LAT:

1. There is an 'aether', the makeup of which is not specified.
2. There is a privileged, albeit unobservable, reference frame where the aether is at rest (isotropic).
3. The (constant) velocity of light results from electromagnetic interactions with waves (and matter), and not from properties of space-time.

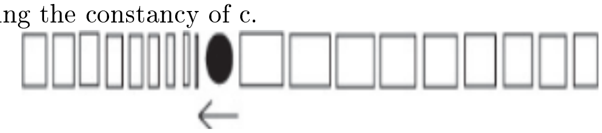
SGS can address these issues: As for 1, the makeup of the aether, SGS says the aether is the space-time itself. And in 1922, Einstein himself said essentially the same thing.

[Note: Einstein (translation)-"Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an ether. According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it"]

2. A privileged reference frame, is also not an issue in SGS. The stochastic nature of space-time makes it impossible to define a *global* rest frame. But we can consider a *local* privileged reference frame where the correlation region (the region where we can consider a background privileged frame) is large compared to the region where we are doing experiments.

3. The constancy of the speed of light not a result of the properties of space-time, can be addressed as well. While there is nothing wrong with the LAT derivation of the constancy, we can give a qualitative geometrical model as an alternate way of thinking about the constancy:

We maintain that frame-draging occurs whenever a mass (non-zero rest mass) moves through space-time. Photons, as their rest mass is zero, moves without frame-draging. This (as we will see) allows an argument showing the constancy of c.



Consider an object (here, the black circle) moving at high speed in the direction of the arrow. The object moves through the venues (here represented by the white rectangles). But due to venue frame dragging at high velocities, the venues are pushed ahead of the moving object. But venues are constant in (5-D) volume, and the only way that they can 'pile up' is by contracting in the direction of motion (and expanding in other dimensions). The object must move through these venues. As the object's speed increases, the contraction increases (rather in the way a 'curvature well' becomes ever deeper). To an external observer (making contravariant observations), the objects increase in velocity slows until it stops completely where the venue dimension in the direction of motion approaches zero. To that observer (as can be seen in the diagram above) the object is accelerating (which because of the Equivalence Principle, is under the influence of gravity). This establishes that a mass has a limiting velocity.

We have postulated that a particle with non-zero rest mass drags along (empty) venues as it moves, Photons, having zero rest mass, do not drag venues.

So, if a particle moving with respect to the local privileged reference frame emits a photon, the photon does initially travel with a velocity of c plus the velocity of the particle. But the particle is dragging venues. As the venue contracts in the direction of motion, since its volume is constant, it expands in the time dimension. And this makes the time a photon takes to pass through the venue constant. The photon has more venues to pass through than it would have if the particle were not moving. Because of the additional distance (i.e. number of venues) the photon needs to travel, its speed at the detector, would be a constant, which is to say c.

If the detector were extremely close to the emitter (on the order of Planck lengths) one would measure a value of the velocity greater than c.

This length scale is too small to measure so the velocity greater than c is unobservable. But other phenomena related to frame dragging might be large enough to detect. A comet in an extremely elliptical orbit or a space-craft 'slingshotting' around a planet might exhibit a detectable motion anomaly.

The SGS model violates Galilean Relativity in that motion is not (in this model) relative. LAT violates it as well. This is allowed (in both cases) by having a privileged reference frame.

With SGS then, there is a new phenomenon at play: 'Velocity Induced Frame-draging'. So, in addition to frame-draging being generated by mass (or acceleration), it is also generated by an object's linear motion in the space-time aether. One way of perhaps justifying this is to consider the conservation of energy, as the sum of potential and kinetic energy. The former is gravity dependent while the other is motion dependent. Since gravity yields curvature, perhaps velocity does as well. Potential then, could be considered a result of Mach's Principle.

Frame-draging has much in common with curvature, specifically Schwarzschild curvature. We might therefore expect the metric tensors to be similar. Indeed, without doing any calculations, we can guess at a metric for the moving object. Consider the g_{11}(the radial component of the Schwarzschild metric) $(1 - \frac{2Gm}{rc^2})^{-1}$. The velocity induced model is not a function of mass, so m and G are unlikely to be in g_{11}. However, note that Gm/rc^2 have units of v^2/c^2, so we might expect g_{11} to be $(1 - k\frac{v^2}{c^2})^{-1}$ where k is a constant. We would expect a (coordinate) singularity to occur when $v = c$, so that would make $k = 1$. A similar argument can be made for g_{00}(the time component).

VI. (BRIEF) DISCUSSION

The aim of 'Stochastic space-time' is to introduce stochasticity into the structure of space-time itself, rather than into the properties of the particles in the space-time. This is an alternate, geometrodynamic, approach to Nelson's groundbreaking model that indeed has matter moving stochastically *in* the space-time.

Because points have no extent, there seemed to be no way to prevent events (points) migrating to the same point. Therefore tessellating space-time would be problematic. So a granular model of space-time seemed necessary. Further, whereas the only geometrical property of an event is its coordinate location, grains, having extent, can have different values of **Δ**x, **Δ**y, **Δ**z, and **Δ**t. And that allows an explanation of curvature within four dimensions (as opposed to explaining it by embedding the four dimensional space-time manifold in a five dimensional Euclidean space). And as long as the 4-volume of the grains (which we call 'venues') is constant, we do not violate Lorentz invariance.

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 version of time, τ-time. The implication is that our usual t-time is just a human construct, not actually intrinsic to space-time.

This paper is an attempt to repair some of the errors and inconsistencies of Part A (which necessitated some new ideas) so that the path to a future, deeper theory will be smoother.

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